Nuclear Waste Management of the Olkiluoto and Loviisa Power Plants

Annual Review 2004

POSIVA

The front cover shows the mouth of the access tunnel to the underground rock characterisation facility, ONKALO, in the initial phase of excavation.

SUMMARY

This report describes the nuclear waste management of the Olkiluoto and Loviisa nuclear power plants. The report includes a description of the status and operations of nuclear waste management of the power companies in 2004, a review of the communication activities pertaining to nuclear waste management, and an account of the provisions made for future waste management costs.

In accordance with the decision taken by the Ministry of Trade and Industry in 2003, the operations related to the final disposal of spent fuel shall progress in such a way that the material required to apply for a construction licence must be ready by the end of 2012. By the same decision, the Ministry set a new intermediate target of 2009, at which time an overview of the material intended for the application for a construction licence must be submitted. On the whole, preparations for the final disposal of spent fuel are progressing in accordance with the programme for the pre-construction phase of the final disposal facility published in 2000 and with the three-year programme “TKS-2003” pertaining to detailed research, development and technical design published in 2003.

For the purpose of the investigations at Olkiluoto for site confirmation, Posiva launched the VARTU research programme, under which the work of the necessary fields of research (geology, geophysics, hydrogeochemistry, hydrogeology, rock mechanics and field investigations) is planned, implemented and reported. Posiva also set up the International Advisory Group for Olkiluoto Investigations, known as the INAGO Group to assess the operations under the VARTU programme.

In the assessment of long-term safety, the main emphasis in 2004 was on studies into the behaviour of engineered barriers, i.e. the copper canister and bentonite, and on the examination of harmful processes. A plan and schedule were drawn up for the safety case to be prepared in support of the application for a construction licence for the final disposal facility.

The design documentation of final disposal canisters was updated. With regard to canister manufacturing technology, one of the principal development subjects continued to be the manufacture of the cylindrical part of the copper canister from one piece, with several optional methods. The cost estimates of the spent fuel transportation alternatives were updated.

Linked with the future use of the underground rock characterisation facility called ONKALO as a part of the nuclear installation, the preparation of a manual for the nuclear material safeguards was launched. The purpose is to put the manual into use during 2005.

In designing the repository, the priorities included developing the low-pH grouting material, the horizontal disposal concept and the backfilling methods, and co-ordinating the design of the repository and ONKALO.

The first tunnel contract for ONKALO was signed in the spring of 2004. The contract covers excavation and structures of the access tunnel to level –417 m and raise boring of the shaft to level –287 m. The excavation work began on 29 June with excavation of the open cut, which was completed on 6 September 2004. The excavation underground began on 22 September 2004, and by the year-end the total length of the tunnel was 157 m.

With regard to operating waste, the established monitoring and long-term investigations and practical measures continued. Construction of the solidification plant for wet wastes began in Loviisa. The plant is scheduled for completion in 2006.

By the end of 2004, 4,683 m^3 of operating waste had accumulated at the Olkiluoto Power Plant, and 2,625 m^3 at Loviisa; 4,140 m^3 of the Olkiluoto waste has been finally disposed of in the VLJ Repository; 1,234 m^3 of the Loviisa waste has been disposed of in the low- and intermediate-level waste repository at Hästholmen.

The decommissioning plans for the power plants were last updated in 2003, and the next revision will be done by the end of 2008.

The overall costs of the research programme for nuclear waste management of the Olkiluoto and Loviisa Power Plants amounted to EUR 14.3 million. On the whole, the research programme was implemented according to plan.

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INTRODUCTION

In Finland, two companies utilise nuclear energy to generate electrical power – Teollisuuden Voima Oy (TVO) and Fortum Power and Heat Oy (hereafter referred to as Fortum). In compliance with the Nuclear Energy Act, TVO and Fortum are liable for all activities associated with management of the nuclear waste they produce, for the appropriate preparation of these activities and for all related costs incurred.

In accordance with the Nuclear Energy Act, the Ministry of Trade and Industry (KTM) makes decisions on the principles that must be applied to nuclear waste management. KTM formulated these principles in its decisions of 19 March 1991, 26 September 1995 and 23 October 2003. The decisions provide a basis for both the practical implementation of nuclear waste management and the research and development related to future measures.

Each company is separately responsible for all measures necessary for the treatment and final disposal of low- and intermediate-level operating waste, and for the decommissioning of the power plants. Posiva Oy, a company jointly owned by TVO and Fortum, is in charge of the research and development of the final disposal of spent nuclear fuel and, ultimately, of the construction and operation of the disposal facility itself.

Posiva is also in charge of compiling the plan for and report on nuclear waste management of the Olkiluoto and Loviisa nuclear power plants, both of which are to be prepared annually. As prescribed by the Nuclear Energy Act and Decree, this Annual Review 2004 describes the status and operations of nuclear waste management in 2004. The report also reviews communication activities pertaining to nuclear waste management and the provisions made for future nuclear waste management costs.

At its Olkiluoto Power Plant in Eurajoki, Teollisuuden Voima Oy operates two boiling water reactors with a nominal output of 840 MWe (net) each. Olkiluoto 1 (OL1) was connected to the Finnish grid in September 1978, and Olkiluoto 2 (OL2) in February 1980. In 2004, the load factors of OL1 and OL2 were 95.1% and 96.1%, respectively. The operating licences for plant units OL1 and OL2, the storage facility for low-level waste (MAJ Store), the storage facility for intermediate-level waste (KAJ Store) and the interim store for spent fuel (KPA Store) will be valid until the end of 2018. The operating licence for the repository for operating waste (VLJ Repository) will be valid until the end of 2051.

Fortum Power and Heat Oy's Loviisa Power Plant has two pressurised water reactors with a nominal output of 488 MWe (net) each. Commercial operation of Loviisa 1 (LO1) began in May 1977, and that of Loviisa 2 (LO2) in January 1981. In 2004, the load factors of LO1 and LO2 were 87.1% and 93.8%, respectively. The operating licences for plant units LO1 and LO2, and the related nuclear fuel and nuclear waste management facilities will be valid until the end of 2007. With respect to the repository for operating waste (VLJ Repository), the operating licence will be valid until the end of 2055.

SPENT FUEL MANAGEMENT

PRINCIPLES AND SCHEDULE

In compliance with the Nuclear Energy Act and the KTM decisions, preparations are underway for the final disposal in Finland's bedrock of all spent fuel from the Olkiluoto Power Plant and the spent fuel stored to date at the Loviisa Power Plant, as well as that which will accumulate hereafter. In its decision of 23 October 2003, KTM revised the schedule for preparations for the final disposal of spent fuel in such a way that the preliminary studies and plans required for a construction licence for the final disposal facility must be submitted in 2009. Provision must be made to submit the final studies and plans by the end of 2012 instead of the previous deadline of 2010. The schedule target set for the beginning of final disposal was kept unchanged, in 2020. In the meantime, spent fuel is stored temporarily at the power plant sites.

In December 2000, the Council of State took a Decision in Principle concerning the final disposal of spent nuclear fuel at Olkiluoto in Eurajoki. Parliament ratified the decision nearly unanimously in May 2001. The final disposal facility, consisting of an encapsulation plant and a repository, will be built in the 2010s. In accordance with the Decision in Principle, an application for a construction licence must be submitted in 2016 at the latest.

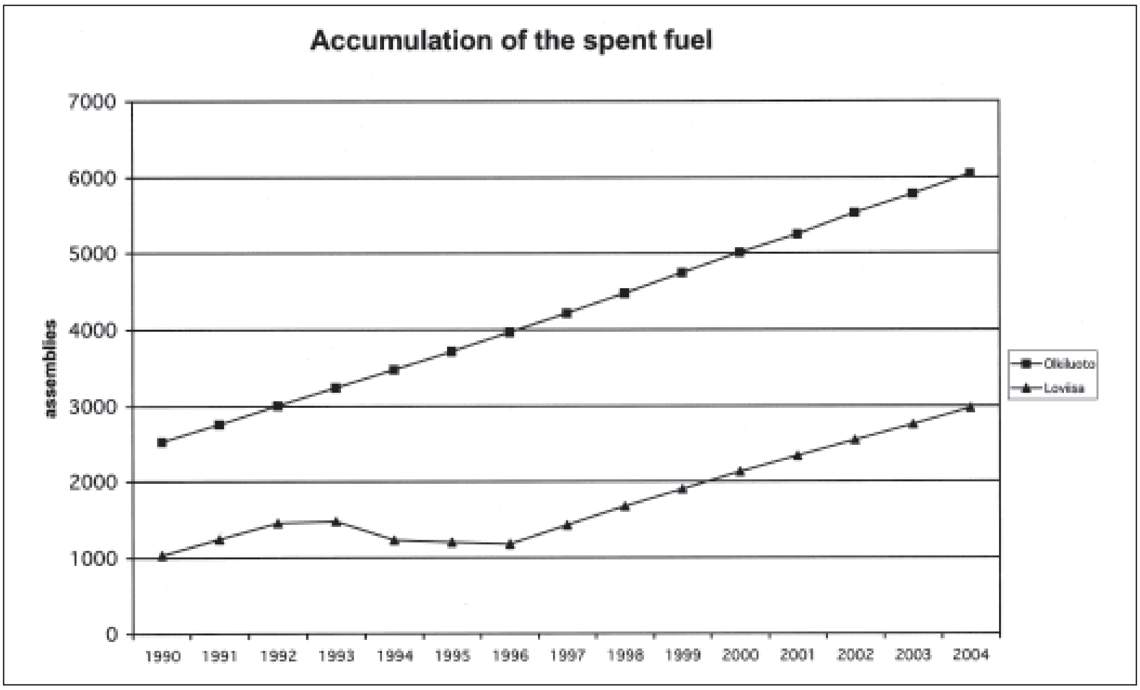
In 2002, a Decision in Principle was taken to construct a new nuclear power plant unit in Finland. At the same time, a Decision in Principle was taken on the extended construction of a final disposal facility for spent nuclear fuel in such a way that the spent fuel from the new plant unit can also be disposed of in the facility. The waste management obligation of the new plant unit will not begin until the commissioning of the plant towards the end of the decade.

Preparations for the final disposal of spent fuel progress in accordance with the long-term programme pertaining to research, development and technical design (TKS) published in 2001. The principal tasks of the current three-year period (2004–2006) have been described in the TKS-2003 programme published towards the end of 2003. The Radiation and Nuclear Safety Authority gave an assessment of the programme in October 2004.

CURRENT STATUS OF STORAGE

Spent fuel from the Olkiluoto plant is stored temporarily at the plant units and in the interim store for spent fuel (KPA Store). In 2004, the storage capacity of the KPA Store was 7,146 assembly positions. The KPA Store has sufficient capacity for the spent fuel accumulated during about 30 years' operation of the plant units. Extension of the storage will be necessary in about 2012. Design work on the extension is about to begin. The twenty-fifth refuelling of Olkiluoto 1 and the twenty-third refuelling of Olkiluoto 2 were carried out during the year under review. At the end of 2004, a total of 6,050 assemblies of spent fuel, equivalent to 1,026 tonnes of fresh uranium were stored at the Olkiluoto plant. The KPA Store housed 4,838 assemblies; the pools of OL1 stored 717 assemblies and those of OL2 stored 495 assemblies.

Return transports of spent fuel from the Loviisa plant to Russia terminated at the end of 1996 owing to an amendment to the Nuclear Energy Act. Subsequently, the storage capacity at



the Loviisa plant was increased in 2000 in such a way that, using racks of the current type, the capacity will be sufficient until 2010. A study into extension of the spent fuel storage capacity was completed in 2004. The study considered the opportunities to enlarge spent fuel store 2 in technical and economic terms. Results of the development work provided what are called the extension options of dense and open fuel racks, which are based on the water pool technology employed in Finland. The extension option of dense fuel racks is based on the storage pools currently in use, while the extension option of open racks is based on the construction of four additional pools as an extension of the existing ones. Invitations to tender for dense racks were sent to seven Finnish equipment manufacturers and six foreign suppliers. The study did not reveal any factors that would prevent the acquisition and introduction of dense racks.

At the end of 2004, a total of 2,947 spent fuel assemblies, equivalent to about 354 tonnes of fresh uranium (estimated on the basis of the amount of uranium contained in the spent fuel, about 336 tonnes), were stored in the Loviisa plant's storage facilities. LO1 housed 204 assemblies and LO2 housed 227. The spent fuel storage facilities 1 and 2 held 450 and 2,066 assemblies, respectively.

INVESTIGATIONS AT OLKILUOTO FOR SITE CONFIRMATION

Overview

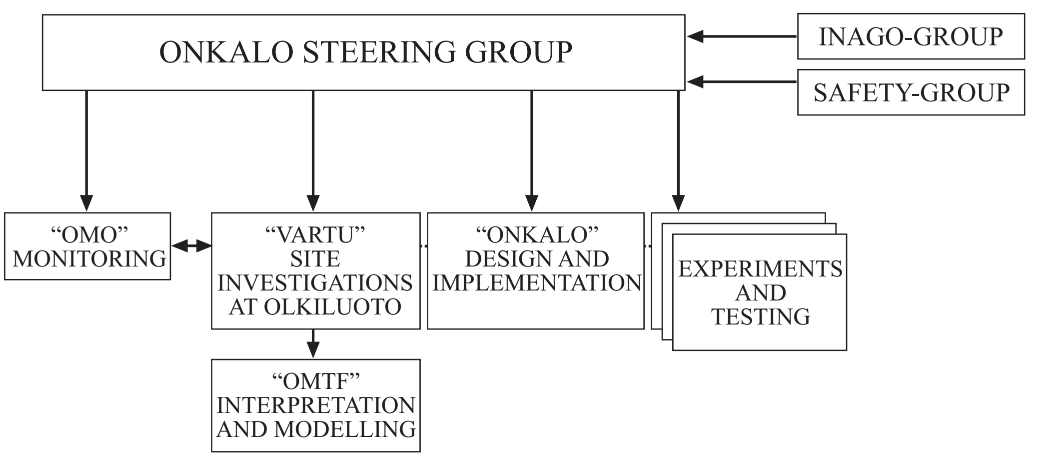
The investigations at Olkiluoto for site confirmation consist of research work in many different fields, and it should be possible to interpret and combine the findings of these studies so as to provide the basic data for development of the final disposal concept, design of the repository and assessment of the safety. To achieve this objective, Posiva launched what is called the VARTU programme, which helps gather the documentation obtained from the different fields and sites of research and enables users of the information to build up an overall picture of the bedrock conditions at Olkiluoto.

The VARTU programme started operations in the beginning of 2004, and its task is to co-ordinate the design, implementation and reporting of the investigations at Olkiluoto for site confirmation during investigation phases 1 and 2 of ONKALO (phase 1: investigations from the ground surface before construction of the access tunnel; phase 2: construction of the access tunnel and the ventilation raise and related investigations). The scope of the programme includes the investigations from both ONKALO and the ground surface.

The co-ordination aims to intersperse the research operations with the implementation of ONKALO in the best possible manner and to opportunely serve the further design of ONKALO as well as the development work on and technical design of the final disposal concept. The VARTU programme is therefore closely connected with other ONKALO -tasks, such as the design and monitoring of ONKALO. The tasks also include seeing to the overall interpretation of the different fields and sites of research (synthesis, integration). To this end, a special interpretation and modelling work group entitled the Olkiluoto Modelling Task Force (OMTF) was set up under the VARTU programme.

Principal Co-ordinators for each field of research (geology, geophysics, hydrogeochemistry, hydrogeology, rock mechanics and field investigations) are responsible for the design, implementation and reporting of the VARTU research programme. A co-ordination group, led by the Programme Co-ordinator, is responsible for the co-ordination of the research, development and design tasks as well as for meeting the overall targets set for the programme. The members of the group include the above-mentioned co-ordinators and the leader of the Modelling Task Force (OMTF). The co-ordination group convened 13 times in 2004.

ORGANISATION OF THE ONKALO TASKS AT POSIVA



The primary task of the OMTF is to interpret and model the results of site investigations in an integrated manner, which serves both the implementation of ONKALO and the development work on the final disposal concept as well as the assessment of its long-term safety. The OMTF consists of four modelling groups (geology, hydrogeochemistry, hydrogeology and rock mechanics), whose leaders are members of the OMTF's Core Group. It is led by the head of the OMTF, and the members also include the representatives of the long-term safety group and the VARTU programme. In 2004, the OMTF's Core Group convened 13 times. During the year under review, the most important task was to draw up the Site Descriptive Report 2004 on Olkiluoto, which constituted at the same time the updating of the 2003 Baseline Report. The report will be published in the first half of 2005.

In 2004, Posiva also set up the International Advisory Group for Olkiluoto Investigations, known as the INAGO Group to assess the operations under the VARTU programme. The group comprises six members from different fields of research, and they represent the waste management organisations of five countries. The INAGO Group convened twice in 2004.

The Radiation and Nuclear Safety Authority (STUK), supported by international groups of experts, assessed the progress of the research done under the VARTU programme. In 2004, STUK drew up a list of open issues, whose first version includes a total of 36 issues pertaining to the research, monitoring and modelling related to ONKALO. The open issues have been classified into three urgency categories: those to be settled immediately (in about a year), those to be settled in a few years, and those to be settled before applying for a building permit. Once an issue has been settled in an acceptable manner, it can be removed from the list. New issues can also be put on the list as the investigations for site confirmation progress. The purpose is to deal with the open issues at meetings to be arranged twice a year. The first monitoring meeting of this kind was held in the autumn of 2004.

Investigations in accordance with the VARTU programme carried out in 2004 are discussed below by field of research.

Geology

Geological investigations from the ground surface

During 2004, the geological properties of the Olkiluoto bedrock were studied from the ground surface with the aid of outcrop mapping, investigation trenches and drillings. The purpose of the investigations was to establish the properties of the geological features in the Olkiluoto area and to specify the current bedrock model. Furthermore, the investigations are aimed to increase the geological predictability.

Geological outcrop mapping was concentrated on the eastern part of Olkiluoto, and their purpose was to gain deeper insight into the different deformation phases of the bedrock and the distribution of rock types on the island. During the outcrop mapping, efforts were made to systematically review all outcrops in the eastern part of the island and to survey the structures that could be detected from them, such as schistosity, folding and fracturing. The outcrop observations totalled more than 200.

Four new investigation trenches (TK8-TK11) were dug at the Olkiluoto investigation site; their total length was some 1,200 metres. The rock types, all fractures and the detectable plastic structures (e.g. schistosity and fold axes) were analysed from the trenches.

Investigation trench TK4 dug in the south-north direction in the central part of the island in 2003 was extended to the north as investigation trench TK8. The purpose of the trench was to provide deeper insight into the 2D and 3D structure of the large fold structure that could be detected with geophysical methods, to establish the fracture systematics of bedrock in the northern part of the island and to investigate the properties of structures RH20A and RH20B. Furthermore, the trench helped sharpen the picture of the distribution of rock types on the island. The final length of the trench was 760 metres, and about 1,700 fractures in all were analysed from the trench.

Investigation trench TK9 was dug in the central part of the island, in the vicinity of investigation trench TK3 dug in 2002. The purpose of the investigation trench was to provide new insight into the structure of the bedrock and the fracture systematics in the western part of the Olkiluoto investigation site. In addition, the purpose was to obtain additional information on the properties of the fracture zone detected in trench TK3. Examination of the properties of the structure concerned is of great importance in designing the location of the repository west of the investigation site.

Two smaller trenches were also dug at Olkiluoto. Investigation trench TK10 was dug in the eastern part of the Olkiluoto investigation site, between boreholes OL-KR9 and OL-KR11, on the basis of the outcrop mapping and geophysical anomalies. The end of the potential large fold structure that can be detected with geophysical methods is exactly located in the area concerned, and what is more the outcrop mapping conducted during 2004 support the above-mentioned geophysical observation. The trench is aimed to establish the geometry of the fold structure concerned and its relation to the brittle structures discovered on the island. With respect to trench TK10, geological surveys are still unfinished and continue during 2005.

Investigation trench TK11 was dug at the Olkiluoto investigation site during the construction of the storage hall foundations completed in the summer. The investigation trench is located along the line of the access tunnel to ONKALO and partly above investigation trench TK7. All fractures, rock types and deformation structures were analysed from the trench. The co-ordinates of each fracture were defined with the aid of a tacheometer. The acquired data helped make a detailed fracture map of the trench, which can be further utilised in studying the fracture systematics in the area and in predicting the fracturing of the access tunnel to ONKALO. More than 2,000 fracture observations were made from the trench. Furthermore, a brittle fault in the north-south direction was detected in the trench, whose relative vergences could be determined on the basis of geological observations. The observations show that the east side of the fault had moved at least 2 metres northwards in relation to the west side of the fault.

Five new deep boreholes (OL-KR29–OL-KR33) were drilled at the Olkiluoto investigation site; the length of the boreholes totalled some 1,660 metres. In addition, existing borehole OL-KR23 was extended to a length of 460 metres. With regard to drillings, the main emphasis was placed on specification of the properties and continuity of structures RH19A, RH19B, RH20A and RH20B. Moreover, the purpose of borehole OL-KR33 was to provide new insight into the strike and properties of the fracture detected in investigation trench TK3 in deeper parts of the bedrock and into the structure of bedrock in the western part of Olkiluoto. On the other hand, the purpose of OL-KR29 was to specify the properties of the bedrock in the southern part of Olkiluoto, and this borehole will serve as what is called the monitoring borehole south of ONKALO.

The new research hall in the area of ONKALO was put into use in the summer. In the research hall there is, for instance, a drill core laboratory, which has considerably accelerated the analysis of drill cores.

Geological mapping of ONKALO

Geological mapping of the excavated surfaces began as part of the excavation work of ONKALO. The open cut leading to ONKALO was mapped first. The mapping included, for example, documentation of the rock types and rock fracturing in the same manner as in tunnel mapping. When the tunnel excavation had got started towards the end of September, the tunnel roof and walls were mapped after every excavation round. During the mapping, the data recorded included, e.g., the rock type, alteration/degradation, bedrock fracturing, schistosity and other features of structural geology, water seepages and fracture zones. The observations are bound to the benchmarks in the tunnel and their actual co-ordinates. About 150 metres of the tunnel were mapped during 2004, which means more than 2,500 square metres in terms of area. More than 2,100 observations of different types (fracturing, schistosity, fold axis, etc.) were made from the mapped section and, in addition, exact co-ordinates were measured for long fractures and structures. In practice, the mapping is performed by geologists working in pairs in three shifts on discontinuous three-shift work. The mapping progresses simultaneously with the excavation work, which requires that the work is integrated and the mapping developed so as to be flexible and appropriate. Furthermore, the data produced shall be available to the designers and modelling groups of the tunnel almost immediately after the mapping.

The first pilot borehole of ONKALO (OL-PH1) with a length of about 160 metres was completed in the beginning of the year. The purpose of the pilot borehole was to verify the results of the previous investigations carried out along the tunnel line and to provide initial data for the designers of the grouting and reinforcement of ONKALO. In December, another pilot borehole (ONK-PH2) with a length of 122 metres was drilled in ONKALO. Both the pilot boreholes kept inside the tunnel profile, which was set as an objective.

Geological modelling

The geological modelling group, coordinated by the OMTF (Olkiluoto Modelling Task Force), began operations. During the first part of the year, Posiva brought a new 3D-modelling program, Surpac, into operation. In autumn, the biggest task was the "prediction-outcome" research work begun simultaneously with the excavation of ONKALO, which predicts geological features discovered in the tunnel in two ways. Prediction A consists of the prediction made on the basis of the existing model and other research data, while prediction B is based on the data obtained from the pilot borehole. These predictions help test how well it is possible to predict the geology at Olkiluoto and its special features to be able to later select the correct investigation method for locating the repository bedrock and assessing its suitability for the purpose of designing the repository layout and its construction. Both predictions were made along the first pilot borehole, PH1, during autumn. The predictions were compared with the tunnel mapping data, and preliminary results show that particularly the prediction made on the basis of the pilot borehole held true with respect to the fracture zones and fracturing of the bedrock.

In spring, the modelling group performed a lineament interpretation on the Forsmark investigation site jointly with SKB. The corresponding interpretation on the Olkiluoto site began in the autumn. The interpretation is based on the updating of topographic lineaments and the interpretation of geophysical lineaments. In the next phase, these interpretations will be combined to provide a better picture of the lineament, for instance in the sea areas, and thus reduce uncertainties. Lineament interpretation is needed for studies into potential extension of the investigation area as well as for geological and hydrogeological modelling.

Hydrogeochemistry

The hydrogeochemical description of Olkiluoto (Pitkänen et al. Posiva 2003-07) published in 2003 was complemented by the hydrogeochemical material gathered by the summer of 2004. The comments made on the description of the baseline were also taken into account in the updating, as far as possible. The description represents the current baseline at Olkiluoto before the construction of ONKALO begins. The 3D model published in 2003 was also updated with new results and the calculation of the model was further developed. The purpose is to later use the model to visualise the disturbances caused by ONKALO.

Hydrogeochemical investigations further concentrated on studies into the regional distribution of the salinity, the definition of dissolved gases and the baseline in the investigation area, since the data were needed to update the description of the hydrogeochemical baseline. A total of 29 groundwater samples were taken from deep boreholes. Of these, four water samples belonged to the monitoring programme of the long-term pumping test of OL-KR6 and ten samples to the monitoring programme. Dissolved gases were analysed from a total of 19 water samples and microbes from five samples. The results obtained early in the year were further used for verification and finishing of the description of the hydrogeochemical baseline at Olkiluoto. The results will be reported in English in the first part of 2005.

Water sampling from the shallow boreholes drilled in the bedrock and from the standpipes installed in the ground continued in accordance with the monitoring programme. In the spring, samples were taken from ten sampling points, and microbe samples were also taken at the same time. The samples taken in the autumn totalled 26. In addition, the purpose of the water sampling was to examine the seasonal variations and any disturbances caused during the construction of ONKALO. The results will also be reported in English in the first part of 2005.

Geohydrology

Measurements and interpretation

Hydrogeological measurements were carried out from the observation tubes installed in the ground, from the shallow drillholes and boreholes and from the deep boreholes. More observation tubes were installed and more shallow boreholes were drilled to improve the area coverage of the observation points. Previous measurement results were also analysed and reported. Indeed, deeper insight was gained into the surface-hydrology, and some of the measurements were included in the systematic monitoring programme (OMO).

An updated summary was reported of the results of the long-term pumping test conducted in borehole OL-KR6, and the test was underway throughout the year. A decision was taken to continue the test until the calculated coverage of the test is extensive enough and essential changes in the pumping waters are no longer evident. The occurrence of the different water types, particularly the infiltrating freshwater, current seawater, more saline groundwater and water typical of the Litorina Sea can be identified near the coastline of Olkiluoto Island on the basis of the preliminary results.

Hydraulic conductivity properties of the principal tight bedrock sections of Olkiluoto Island were measured with the hydraulic testing unit (HTU) from boreholes KR12–KR14. The testing unit was developed by adding to it a location option based on the single-point resistance method, by which the comparison between the various measurements with respect to the depth position is on a solid basis.

Simultaneous examination of digital images, other borehole data and hydraulic measurement results has enabled the properties of single hydraulically conductive fractures to be identified and determined for a given fracture. Data of this kind helps give a better picture of the flow of groundwater on the scale of single fractures.

The soil in the area of ONKALO and the hydrological observations made there were studied to assess any effects on surface hydrology produced by the construction of ONKALO. Owing to the vicinity of a Natura 2000 site, special examination of this kind was necessary. A summary of the studies has been presented in a working report.

A pressure interference test was carried out between boreholes OL-KR14–OL-KR18 during the year under review. This test supplemented the flow interference test conducted in 2002. For the pressure interference test, observation boreholes were plugged into sections with the aid of multi-packer equipment, and the development of pressure in each packer interval was measured with pressure transducers. When analysing the results later, the results of these different interference tests will be compared with each other, and the usability of the data obtained from the different tests for understanding the flow of groundwater will be assessed. Preliminary evaluations show that this test also supports the picture of only few single hydraulically conductive fractures built up previously.

Modelling

Previous modelling studies performed for design of the layout of ONKALO were reported as a working report. These studies helped identify the essential features of the disturbances caused and could thus be taken into account in the design. However, the actual extent of the disturbance will depend on the outcome of the final grouting measures implemented during construction.

With regard to the groundwater flow modelling, the main task was to gain a better understanding of the site and to reduce the uncertainties, which constituted the objective set for the investigations for site confirmation. Co-operation with the other fields of research, such as geology, hydrogeochemisty and rock mechanics, was launched within the Olkiluoto Modelling Task Force (OMTF). At first, the flow modelling and hydrogeochemistry groups attempted to work out a compatible idea common to the various fields of research. The work consisted of both updating the picture of the baseline and performing the first advance modellings of the effects of the construction of ONKALO where the first kilometre of the tunnel reaches a depth of 100 metres. The modelling was carried out in 2004 and the report has been completed. A consistent site description report of the disposal site, which also includes a geohydrological description, will be completed in early 2005.

The modelling of groundwater flow in the demanding situation where the density of groundwater and the groundwater level vary locally as well as temporally, owing to the flow, has required coupling the modelling of both the flow and the migration of dissolved matter (salt) as a transient. Success in developing a model for a purpose as complex as this has been a major achievement. In modelling the final disposal situation, the heat generated by waste will be included as well. The current development level will also enable the heat and the consequent alteration in density to be taken into account in the modelling.

Rock mechanics

With respect to rock mechanics, what is called the rock mechanics group was set up, whose purpose is to design and implement the rock mechanical tasks required by the OMTF. The group's tasks included, for example, gathering a summary of all the rock mechanical studies conducted before 2005, carrying out a technical audit of the numerical modelling performed previously, thus striving to enhance the strategy of numerical modelling, building up a picture library of the R/RH structures penetrated by investigation boreholes, examining the connection between the geological structures and the stress, ensuring the acquisition of essential rock mechanical mapping data during the construction of ONKALO, and writing the chapter that deals with rock mechanics in the OMTF site report.

The point load test results obtained from the investigation borehole samples drilled from the ground surface were gathered in a separate report. The strength values calculated from the point load index were divided into six rock types, and the variation between the boreholes and with respect to the depth was also studied. The purpose is to further expand the scope of the work in 2005 while taking the observations of schistosity and the load direction with respect to schistosity into account as well as establishing their correlation with the strength values.

Strength and deformation properties were determined from the samples taken from investigation borehole OL-KR24 (the ventilation raise borehole of ONKALO). The samples were taken from depths of 400–450 m, corresponding to the main characterisation level of ONKALO. The test programme included uniaxial and triaxial tests and tension tests. Some of the uniaxial tests were what are called anisotropy determinations, while some also included the measurements of acoustic emission.

A study was launched at Helsinki University of Technology whose purpose is to study whether the stress can be assessed by loading divergent drill core samples and by observing them with the aid of acoustic emission, or what is called the Kaiser phenomenon. The study to be conducted as a master's thesis will be completed during 2005.

Environmental studies

The monitoring programme launched during the year under review includes most of the environmental studies. The basic survey of the fauna at Olkiluoto was supplemented by studying the species and number of smaller mammals, carabid beetles *(Carabidae)*, beetles *(Coleoptera)* and bats. The comprehensive survey of forests at Olkiluoto, launched in 2002, continued with the first phase of the forest plot inventory, which consisted of gathering data on the tree stand from about 550 observation points distributed at regular locations on the island. Routine monitoring of the composition of rainwater, snow and soil-water continued normally, as did the snow and frost observations. In addition, the monitoring data for the past year on the weather conditions, the marine ecosystems and the radioactivity of the environment gathered by Teollisuuden Voima Oy were also stored in Posiva's archive for subsequent detailed examination.

The monitoring network of the environment was improved by building a weather mast in the observation area established in 2003 for the purpose of monitoring, for instance, the microclimate of the forest stand. Furthermore, this observation area was complemented and a corresponding observation area was established in the old spruce wood located in the same catchment area.

To improve the handling of monitoring and other environmental samples, the working point in the laboratory of the research hall built as part of the ONKALO site, which is intended for the handling of environmental samples, was brought into operation during the year under review. The pretreatment facilities provided there ensure increasingly reliably the quality of the samples up to the actual analysing laboratory.

Equipment and methods

Development work on the equipment known as TERO intended to measure the thermal properties of the bedrock *in situ* continued, and a report on the construction of the equipment was completed. Development work on the interpretation software of the borehole measuring equipment was also launched and the first test measurements in the field were conducted in investigation borehole OL-KR2 at Olkiluoto. After initial problems, the field measurements were technically successful. Posiva also had preliminary discussions about measurements at SKB's investigation sites.

Development work on the interpretation of results from the rock stress measurement based on the overcoring method, carried out jointly with SKB, continued. The development work linked with continuous, isotropic material was practically finished. The purpose is to complete the reporting in early 2005. Design of the development work on the interpretation tools of the next phase, i.e. anisotropic material, began, and the work was agreed to start in the beginning of 2005.

The results of the first development phase of the mass spectrometry (MS) method, which enables determination of the gases dissolved in the groundwater, were reported. The development work otherwise continued to mainly focus on the analysis of gases from the gas phase. In the latter part of the year, the work proceeded to test the determination of gases from the liquid phase using membrane technology. The results of the method development will be reported in 2005.

The single-point resistance measurement option of the hydraulic testing unit (HTU) was put into routine use. The program was further developed in such a manner that comparison with the corresponding measurements conducted with the differential flow measurement unit is possible during measurements, and the data provided by both methods are shown on the display simultaneously. To improve the quality of the data, rotation speed control of the winch was installed in the hydraulic testing unit. This device enables the movement of the borehole equipment at half velocity, or at the same velocity as it is possible to move the differential flow measurement unit. The new electronic cards were put into use, but problems arose in their introduction. Settlement of the problems is being continued in early 2005.

A new differential flow measurement unit was built during the year under review, and its calibration was completed towards the year-end. The unit will be brought into operation in 2005. The purpose of building the equipment is to better meet the increasing measurement needs in ONKALO and above ground. The interpretation program of the differential flow measurement unit was upgraded to be better suitable for measurements in ONKALO. In addition, monitoring programs of the encrustation of the EC transducer and the cable tension were developed.

The field tests of the transverse flow measurement equipment were carried out in investigation borehole OL-KR16 and most of the results were seen to be successful. The rubber guides were found to be too stiff, and consequently they will be further improved. To test the equipment under laboratory conditions and to provide a demonstration site, what is called the artificial fracture will be built, which will enable the visualisation of the migration of water in the fracture and through the flow transducer of the equipment with the aid of a visible tracer. The design of the artificial fracture began.

Additional pressure vessels were manufactured for the PAVE equipment, one with a volume of 300 ml and two with a volume of 150 ml. The hose winch manufactured in 1999 to facilitate lowering the equipment into the investigation borehole was modernised by reducing the size of the winch and by installing it in the frame of a trailer. Furthermore, two new sets of field measurement equipment were built for water sampling to be performed from the ground surface. Extension rods, whose material is carbon fibre, were manufactured for the borehole installation work to be made in ONKALO. Tests showed that the carbon fibre rods were very suitable for the borehole installation work, and they can replace the weaker and heavier aluminium rods.

The nitrogen generator, which replaced the nitrogen batteries, was put into production use for the pumping with the PAVE equipment after test operation. In the autumn, the gaseous nitrogen produced with the nitrogen generator was subjected to quality analyses, which showed that the purity grade was within the promised limits.

Equipment plans were made for monitoring the groundwaters in ONKALO. This automatic measuring system of the ONKALO groundwaters consists of automatically monitoring the parameters of both the measuring weirs and the groundwater stations. During the year under review, the plans progressed to such a stage that the system supplier was selected at the end of the year. The implementation of the system will start in the beginning of 2005. To test the measuring weir box, one box with a V-shaped opening was manufactured of steel, and it was calibrated using V-shaped openings of different sizes.

Development work on the gas sampling methods was carried out as both a literature study and practical tests. Gas samples were taken as part of the PAVE -pumping from the ground surface directly into the PAVE vessel. The samples were measured with the aid of a mass spectrometer, whose method development also continues to be underway. The results were good, so further development work on the gas sampling method is being continued in 2005. The results of the development work will be reported during 2005.

Integration

The Olkiluoto Modelling Task Force (OMTF) began operations with a view to integrating the modelling of the different fields of research and to forming a common, compatible and consistent opinion about the final disposal site on the basis of the modelling results in the different fields. The bases for the integration and its objectives have been described in the Underground Characterisation and Research Programme (UCRP). Practical arrangements of the work and aspects to be considered in it have also been described in the TKS-2003 programme.

Having operated for about a year, the OMTF drew up a plan for its operations and started co-operation between the fields of research to produce the first common and consistent description of the final disposal site, or a site report. Essential parts of the report were completed, and the report will be ready for press and published in early 2005.

Launching the work of the modelling groups of the different fields of research, i.e. geology, rock mechanics, hydrology and geochemistry, has taken the bulk of the time, but the needs for information exchange and the forms of interaction between the fields have now been surveyed and described in the site report.

The integration advanced farthest in the co-operation with the fields of hydrology and geochemistry. It was possible to provide a consistent description of the palaeohydrological and palaeogeochemical evolution of Olkiluoto Island that tallies with the site data. The integration is a very laborious process, and the nature and number of parameters, hypotheses and simplifications necessary for the modelling contribute to the opportunity to succeed in fitting the modelling results to the measured ones. However, apparent contradictions can be eliminated by considering the modelling results of any field iteratively, and comparing them with the results of other fields of research.

The research results to be obtained from ONKALO, combined with other site data will eliminate current deficiencies in the basic data required by the models. It can be expected that, in the next round of integration, the results will be specified, thus building confidence in their ability to describe future development and providing an increasingly solid basis for presenting the safety case.

The intensive observation area of a forest. Duckboards have been built in the area in order not to disturb the monitoring of water infiltrating into the soil. The orange rain-water collectors and the green forest litter collectors help monitor the properties of the material falling onto the ground. The structure of the observation area is the same as in the pan-European monitoring programme of the health of forests (level II), whose observation areas number 31 all over Finland, thus providing excellent reference material.

In 2004, the previous studies into the fauna at Olkiluoto were supplemented by field inventories and interviews with local hunters. In terms of its species, Olkiluoto does not very much differ from the rest of south-western Finland.
(Photo: Juha Leppävuori, Metsätähti Ltd.)

MONITORING THE EFFECTS OF ONKALO

Any effects produced by the construction of ONKALO are being monitored by means of a monitoring programme specially drawn up for this purpose. The monitoring programme consists of rock mechanical, geohydrological and hydrogeochemical monitoring as well as monitoring of the environment and foreign substances. As the excavation of ONKALO progresses, measurements will also be conducted underground, but the measurements and investigations carried out in 2004 took place from the ground surface.

The rock mechanical monitoring programme comprised the measurements of the GPS stations and the microseismic stations. Geohydrological monitoring was performed in both open and multi-plugged boreholes by measuring the groundwater level and pressure head. In addition to these, measurements pertained to precipitation (including snow), seawater level, frost thickness and surface runoff. The scope of geochemical monitoring included water sampling from open and multi-plugged boreholes, sampling from shallow boreholes and groundwater pipes, and monitoring the chemistry of the water pumped from ONKALO. The natriumfluoresceine content of the water used for the excavation of ONKALO was also measured.

Potential changes occurring in the environment were monitored by observing the water circulation in a forest stand, by studying the vegetation and small animals, and by monitoring the condition of household water wells. In addition, the amount of dust and the noise level were measured, and aerial photographs were taken of the area.

A materials manual was drawn up of the permissible substances used for the construction of ONKALO, and a record was kept of the amounts of materials used in ONKALO.

The construction of ONKALO has produced no effect on the monitoring results.

ASSESSMENT OF LONG-TERM SAFETY

Studies on the performance of engineered barriers

Engineered barriers constitute an important factor in ensuring the long-term safety in Posiva's safety concept. The concept description included in the TKS-2003 programme states that safety is primarily based on the long-term isolation of radionuclides in waste canisters and on the engineered barriers that ensure the integrity of these canisters as well as on the natural conditions and processes. The performance studies have therefore been focused on establishing the behaviour of the copper canister and its protective bentonite and on examining the harmful processes. The following subjects, in particular, were dealt with in Posiva's own investigations and in studies conducted as international joint projects in 2004.

Bentonite studies

The high pH released from cement has been assessed to produce detrimental effects on the mineralogical properties of bentonite, thus reducing, for example, the swelling pressure. An international working meeting, which discussed interaction between cement and bentonite, was arranged in Tokyo in April 2004 as a co-operation project of NUMO and Posiva (Posiva's Working Report 2004-25). Interactions between cement and bentonite were also investigated within the EU project named ECOCLAY II. The final report of the project was delayed over a year, but the final version has now been completed and the report will be published in the beginning of 2005. The Finnish contribution to the studies will be reported at roughly the same time.

Extensive studies into other processes occurring in bentonite over a long time are being conducted in the LOT test (Long-Term Test of Buffer Material). The tests begun in 1999 have been planned to last for 1, 5 and 20 years. In 2004, preparations were made to analyse the second test borehole, which will probably take place in 2005. In a larger-scale test, under the FEBEX II project, Posiva took part in assessing the obtained results and in final reporting. A summary report of the project is likely to be completed in the beginning of 2005. Monitoring of this long-term test will continue under the EU's NF-PRO project.

In 2003, SKB and Posiva jointly launched a large-scale test pertaining to the gas injection of bentonite buffer. The objective of this international LASGIT project is to carry out gas injection tests of moistened bentonite buffer on a large scale and under realistic conditions, and to interpret the results obtained from them. The objective is to quantitatively establish the physical phenomenon linked with the gas migration process and to validate the modelling of the gas migration process. The test arrangements include a final disposal hole at the Äspö Hard Rock Laboratory. A bentonite buffer in accordance with the KBS-3V concept and a canister fitted with water and gas supply systems and with versatile instrumentation will be placed in the final disposal hole. The systems and components were manufactured in 2004 and they were calibrated and tested in the research facility towards the end of the year. The actual installation of the equipment in the final disposal hole will take place in January 2005. The installation and the sealing of the hole will be followed by the moistening phase of the bentonite, which will last for about two years, after which various gas injection tests will be conducted in about 2007.

Other investigations in the near-field

Phenomena in the near-field and the behaviour of engineered barriers as a whole were tested and demonstrated in the EU's "Prototype Repository" project, which ended in 2004. The KBS-3 final disposal concept was studied in a sealed final disposal tunnel in a full-scale long-term test. Posiva and the Technical Research Centre of Finland (VTT) were involved in developing the conceptual and mathematical modelling of engineered barriers. A report was drawn up on the geochemical changes that occur during the moistening of the tunnel backfilling material and bentonite buffer. The report also deals with time-dependent changes that take place in the engineered barrier system on the edges of the repository. Until further notice, SKB will continue with this work as its internal project. Posiva will continue co-operating with SKB in 2005 and model changes in the porewater of the buffer and backfilling materials.

The performance of engineered barriers and the requirements set for them are handled more extensively in international co-operation in the annual working meetings of the NEA's "Engineering barrier systems" project.

The project "Understanding and Physical and Numerical Modelling of the Key Processes in the Near-Field, and Their Couplings for Different Host Rocks and Repository Strategies (NF-PRO)", which is included in the EU's sixth framework programme, was launched in 2004. The total volume of the four-year project is some EUR 16 million, and the participants include 40 waste management organisations and research institutes. The contributions of Posiva and the research institutes supported by it concern studies into

- the effect of alpha radiolysis on degradation of the fuel matrix;
- the stability of the fuel matrix under high pH conditions;
- the evolution of the porewater chemistry of bentonite (pH, Eh, ionic strength);
- interactions between the corrosion products of copper and iron and bentonite;
- the thermohydromechanical (THM) modelling of the KBS-3V final disposal concept. The modelling work was mostly carried out in 2004 and it will be reported in 2005.
- the evolution, mass and energy balances, energy flows and performance analysis of the near-field.

The studies will be reported later in the manner described in the project plan. The work also includes integrating the results and assessing them from the viewpoint of long-term safety.

SKB and Posiva jointly continued experimental corrosion research particularly in a saline groundwater environment. The investigation carried out in Canada continued, which pertains to modelling the behaviour of the corrosion potential of copper in compacted bentonite containing sulphide on the basis of experimental results. Furthermore, a study was launched with a view to establishing the stress corrosion of copper caused by acetate. Investigations into the redox conditions prevailing in bentonite and their measuring methods also continued.

The bedrock as a barrier

The EU project named "RETROCK", which studied the migration and retention occurring in the bedrock, was completed in 2004 and completion of the final reports is underway. These extensive studies concerned the concepts linked with migration, and their modelling.

International co-operation on the studies into the migration phenomena continued at the Äspö Hard Rock Laboratory. New results were obtained from the TRUE Block Scale tests in order for modelling. The Task Force for Groundwater Flow and Solute Transport continued to focus on studies into heterogeneity as well as the extrapolations of both flow and migration for a situation corresponding to the final disposal conditions.

Sorption tests continued by studying the retention of europium on rock surfaces treated with Cs-containing saline Olkiluoto waters. After a fairly rapid initial outlet, a significant proportion of Eu, whose retention time is considerably longer, remained in the column. The test will be continued in order to sharpen the picture of the reduction velocity of the content of released Eu and possibly the reasons for the retention. To gain a better understanding of the sorption of caesium, studies concentrated on the exchangeable cations of the biotite fractions separated from core samples and on the sorption isotherms of Na, Ca and Cs.

Research aimed at defining the sorption mechanisms of europium and americium continued by studying their retention in kaolinite. The research will be continued within the FUNMIG project, which is being launched. In 2004, Posiva continued to be involved in the work of the second phase of the NEA's "Sorption Forum" project and the third phase of the TDB (Thermodynamic Data Base) project. The final report on the work done during the second phase of the "Sorption Forum" project is being completed in the first part of 2005.

Posiva was involved in the preparation phase of the FUNMIG (Fundamental Processes of Radionuclide Migration) project, which is included in the EU's sixth framework programme. The objective of the FUNMIG project is to gain a basic understanding of migration in the geosphere, taking account of the final disposal concepts developed in different countries and the prevailing bedrock conditions. The project also aims to introduce the latest available knowledge about the migration processes as general tools and models for the assessments of long-term safety. The project was launched in the beginning of 2005 and it will be completed at the end of 2008. The participants in the project include about 50 organisations in all from different countries. In Finland, the University of Helsinki, the Technical Research Centre of Finland (VTT) and Helsinki University of Technology are involved in the project in addition to Posiva. The Finnish contribution to the investigations consists, for instance, of examining the sorption of Ni, Am and Eu, the sorption mechanisms and the chemistry of minerals that dominate the retention in rocks as well as of modelling the results. Furthermore, studies are being conducted to establish the opportunities to utilise redox-sensitive natural materials to discover and interpret the redox changes in the bedrock. Development work carried out in Finland also includes methods for determining the porosity and pore structure of rock.

Concepts and the safety case

Posiva and SKB jointly launched a study concerning the horizontal location of the canister, which is scheduled for 2004–2007. In the KBS-3H concept, the canister and bentonite blocks are packed into perforated steel drums and installed in about 200-m-long horizontal disposal tunnels. The objective is to establish the suitability of the KBS-3H concept and to technically demonstrate the feasibility in practice. To this end, two full-scale disposal tunnels will be drilled and the manufacture of the installation equipment for the canisters and bentonite blocks will be commissioned.

Biosphere studies

Guidelines for the biosphere studies and modelling were further defined on the basis of the needs for a safety analysis necessary for the application for a construction licence in what is called the safety case plan, which will be published in the first part of 2005.

The project, which will run over many years and aims to describe the future of the Olkiluoto biosphere, began by establishing the location of the coastline and the ground level in the area in different eras. In the beginning of 2005, a summary report will be completed on the data gathered from the soil investigations at Olkiluoto, particularly from the viewpoint of the modelling interface of geosphere and biosphere. The readiness for modelling was further stepped up jointly with SKB by continuing the development of the tool tailored for the Matlab/Simulink calculation environment begun in 2003. In addition, a master's thesis was launched towards the end of the year in collaboration with the University of Kuopio about the radioactivity of forest ecosystems.

The second year of operation of the BIOPROTA project, partly financed by Posiva, ended in autumn 2004, and produced useful work material. The joint project of the nuclear waste management organisations concentrates on establishing the key issues of biosphere modelling. The project will be reorganised and it is being continued in 2005 partly with previous themes and partly with new ones.

Posiva continued to monitor the progress of other international projects linked with biosphere modelling. It was also involved in the work of the end user group of the ERICA project dealing with the assessment of radiation exposure of the environment and in the work of the Finnish backers of the project organised by the Ministry of the Environment. Moreover, Posiva and the Finnish Forest Research Institute attended the conference on radioecology (ECORAD) held in France in the autumn with a joint lecture on the development of soil ecosystems. The main theme of the conference was radiation protection of the environment.

Safety analysis

A plan and general schedule were drawn up for the safety case to be prepared in support of the application for a construction licence for the repository, which will be published in the Posiva series of reports in the beginning of 2005. The safety case constitutes a summary of the analyses and other evidence that demonstrates the final disposal concept to be safe. The safety case will be compiled in a report package containing about ten main reports, which are to be updated at certain intervals. The ***Site report*** will form the basis in terms of geosciences and contain a description of the present conditions in the Olkiluoto bedrock, the previous evolution of the conditions and the changes that the construction of the first phase of ONKALO and the repository will effect before operation of the repository begins in 2020. The technological basis will be provided by the reports that describe and justify the ***Properties of spent fuel***, the ***Canister*** and the ***Repository***. The scientific cornerstones of the safety case will be the ***Process report***, which will describe the phenomena and events that affect the functioning of the final disposal system, and the report on the ***Development of the final disposal site and the repository***. The last-mentioned report will describe and analyse the development of the final disposal system from the disposal of the first canisters until the very distant future (some million years). Radiation safety and compliance with the related regulations issued by the authorities will be discussed in four reports: the ***Biosphere***, the ***Release of radionuclides*** (a numerical safety analysis), ***Supplementary safety studies*** (for example, natural analogues) and the ***Summary***, in which the safety case will be gathered.

FINAL DISPOSAL TECHNOLOGY

General

The facility description report published by Posiva at the end of 2003 was translated into English. The cost estimate, which is based on the facility design, was made during 2004 and it will be published as a report in English in 2005. Work on the development and design linked with final disposal is being continued towards the next intermediate stage in 2006, when the updated facility designs and facility description will be published.

Close collaboration with SKB continued, and the projects carried out jointly number several tens. Posiva closely monitors SKB's design project of the encapsulation plant.

Canister design

The canister design documentation was updated. The design documents describe the detailed structure of the canisters, the canister manufacturing technology, including the manufacturing tolerances and quality assurance, and the encapsulation process, including the handling, sealing and inspection of canisters and their transportation to the final disposal hole. The design documents define the design bases for the canister, demonstrate the fulfilment of the design requirements and assess the results of design analyses.

The canister structure consists of a cylindrical massive insert made of nodular cast iron and a 50-mm-thick copper canister. Three versions of the canister have been designed, one for each reactor type operated in Finland. The fuel assemblies are placed in the canister in one piece, including any flow channels belonging to them. The different versions of the canister may hold a maximum of 12 BWR fuel assemblies, 12 VVER 440 fuel assemblies or 4 EPR assemblies. Each canister will contain 1.4 to 2.2 tonnes of uranium, depending on the fuel properties. The external diameter of the canister is 1.05 m in all variations, but the total lengths are 3.6 m for the VVER 440 fuel assembly, 4.8 m for the BWR assembly and 5.2 m for the EPR assembly. The total weights are 18.6, 24.3 and 29.1 tonnes, respectively.

Both the insert and the copper canister can be manufactured using an integrated bottom. With regard to the copper canister, another alternative is a tube manufactured by extrusion or forging, with welded lids at both ends.

There should be a high probability that the canister will maintain its integrity for some 100 000 years. In addition to the good tightness and corrosion resistance, the good and long-lasting integrity requires sufficient mechanical strength, which has been verified by the analyses described in the design documents. The load hypotheses of the analyses include the hydrostatic pressure of groundwater, the even and uneven swelling pressure of bentonite, the thermal effects produced by the decay heat of spent fuel, and the additional hydrostatic pressure caused by a 3-km-thick glacier. The permissible stresses and elongations have been determined in such a manner that reasonable safety factors are achieved in all the design-basis load cases.

The documents give the mechanical design calculations for all the three canister variations. The mechanical strength of the canister is excellent even in cases of uneven or bending load caused by swelling of the bentonite and the load resulting from rock movements or a 3-km-thick glacier. Calculations show that the compression load caused by an external pressure is no less than 100 MPa.

The canister has been designed in such a way that it reduces the radiation on the canister surface to so low a level that the radiation does not unreasonably hamper the handling and transportation of the canister and that the radiation does not cause significant radiolysis in the groundwater. Furthermore, the canister insert has been designed to keep the fuel assemblies in the subcritical geometry even in such a case that the empty space inside the canister would be filled with water and, with respect to OL1–2 and LO1–2, the fuel may be unused or the fuel may exceed a certain burn-up limit owing to the larger assembly of the OL3 plant.

The mechanical strength of the canister was determined experimentally by manufacturing a 700-mm-long test sample from a partly failed insert. The mock-up was surrounded by a 50-mm-thick copper canister and bolted lids. A pressure test was carried out with an isostatic press in a pressure vessel, raising the pressure in stages. At a pressure of about 100 MPa, a plastic deflection of about 5 mm was produced in the test sample wall. The test was continued to a pressure of 130 MPa, when a plastic deflection of about 20 mm was discovered in the thinnest point of the wall. Further investigations showed that the square hollow sections of the insert had buckled and detached from the cast insert, but no new failures occurred in the cast insert.

The acceptance criteria for canister manufacturing technology were considered jointly with SKB, but the preparation of a final proposal was further postponed.

Canister manufacturing technology

With regard to canister manufacturing technology, one of the principal development subjects continued to be the manufacture of the cylindrical part of the copper canister from one piece with several optional manufacturing methods. Manufacturing methods were developed both under the TEKES product development project of Posiva and Outokumpu Poricopper, and as co-operation projects with SKB. The TEKES product development project finished at the end of November 2004 and in the future the manufacturing methods will be developed as Posiva-SKB joint projects with the component manufacturers.

Development work on the copper canister material continued jointly with Outokumpu Poricopper by casting a total of ten billets in three cast series. The beginning of the billet casting process was developed to reduce the central cracking, and the lifting capacity of the foundry was increased and as a result it was possible to cast billets of record weight, even 16.6 tonnes. Owing to this, an increasingly long piece can be removed from the base of the billet in order to minimise casting defects. Of the cast billets, one billet was chosen for examination by machining it axially to the very centre and by conducting a liquid penetrant test at intervals of 20 mm to discover any casting defects. No defects were discovered by the depth of the first 350 mm, but thereafter a centre crack was found in the lower end of the casting. Samples were taken from the billet for analyses of the chemical composition and metallographic examinations.

Two copper canisters with an integrated bottom were manufactured jointly with SKB with the “pierce and draw” method at the tube factory of Vallourec & Mannesmann Tubes in Germany. The method development focused on hot-forming the bottom in order to achieve a grain size of less than 360 mm throughout the bottom, since in other respects the canisters have already fulfilled the technical requirements set for them. In accordance with the plans of the research team set up by Vallourec & Mannesmann, the mandrel and the counterpart of the last phase of the hot-forming process were modified, but the grain structure of the bottom hot-formed with them continued to be uneven and the grain size slightly too large. On the basis of these results, the research team designed new tools once again. The grain size of the wall of the canister manufactured by the process was slightly more uneven than in the canisters examined to date. In the bottom, areas with different deformation grades could be detected; the grain size requirement was achieved in some of them, but not in others. In terms of the dimensions, the canister met the requirements.

Forging tests of the copper canister continued under a joint project of Posiva and SKB. To achieve an even form and an appropriate inner diameter of the tube, a new pair of tools was ordered for use in the last phase of the forging process. A new tube of full length was forged using the new tools, but the inner diameter again became too large. Furthermore, cracks with a length of even 200 mm were formed at one end of the tube during the hot-forming; studies of their reasons began. The temperature of the tube to be hot-formed lowered considerably in the last phase of the hot-forming, whose effect was examined at raised temperatures by means of tensile and compression tests carried out with Gleeble equipment at the University of Oulu. In addition, Kungliga Tekniska Högskolan (KTH) in Stockholm numerically modelled the flow of material during the forging process to find the optimal hot-forming method.

Within the joint project of Posiva and SKB, four new copper tubes with a wall thickness of 50 mm were extruded at Wyman-Gordon in Scotland. The results of the extrusion process were fairly good, and consequently no changes were made in the process, since the objective of the development work was to demonstrate the repeatability of the process while maintaining uniform quality. Preliminary results show that the extruded tubes fulfilled the requirements set for them, except for slight deviation in straightness.

A casting test of the canister insert made of nodular cast iron was carried out at Metso Paper Oy's Rautpohja Foundry. The casting test was again designed jointly with SKB, which continued similar casting tests at three foundries in Sweden. The targets and quality requirements of the tests were consistent, such as to improve the toughness and tensile properties. The insert was cast with an integrated bottom and the screws that fix the cassette (forming the channels for the fuel assemblies) to the mould were strengthened to prevent the cassette from moving during casting. The insert fulfilled the requirements for the main dimensions and the straightness, concentricity and size of the holes, but the mechanical properties of the casting in the upper part of the insert remained clearly below the requirements. Metallographic examinations show that the reason for this is the slag entrapped in the insert during solidification and the incomplete nodulising of the graphite.

A summary report was drawn up on the canister manufacturing costs with the different manufacturing methods and routes. The cost calculations are based on current prices that are estimated for production in series, however. The manufacturing costs of a BWR canister manufactured with the "pierce and draw" method and with an integrated bottom are EUR 135 000. The manufacturing costs of an extruded canister are about 6% higher and those of a forged canister about 6% lower. The costs of a VVER 440 canister are about 10% cheaper, but it is very difficult to assess the costs of EPR canisters, since their manufacture will extend so far into the future.

Canister sealing and inspection technology

Test programmes and development work on the high-vacuum electron beam welding (EBW) method intended for sealing the copper lid of the canister were concentrated to be conducted within the scope of the co-operation agreement signed between Patria Aviation and Posiva. The electron beam welding equipment employed by Patria, located at Linnavuori in Nokia, was modified to be suitable for the welding of thick copper; for instance, the welding power of the equipment was raised to 50 kW and the vacuum equipment was replaced. As early as in the start-up phase of the welding equipment it was possible to implement the first set of the welding test programme by means of plate tests. The final target of the programme is to verify the welding parameters suitable for sealing the copper lid. During the latter part of the year, two more series of plates were welded to determine the optimal welding parameters, for instance, the focus of the electron beam, the weld gap, the beginning, the ending, the overlapping weld and the welding speed. Moreover, temperatures were measured at different points of the plate during welding. In planning the tests, statistical methods, such as the Taguchi and response surface methods, were used to ensure the systematics and to minimise the number of tests. The methods used to examine the plate test welds included radiography and acoustic microscope (SAM) and metallography. The welding tests of copper lids begin immediately in 2005 and, from now on, plans have been made to carry out six series of welding tests a year.

The heat transfer in a copper plate during electron beam welding was modelled at Tampere University of Technology. The purpose of the work was to determine the effect of the size and form of a welding test sample on its temperature, with a view to establishing whether the plate tests and the future tests on short canister tubes correspond to the welding of the lid. Temperatures measured from the test samples and those to be measured later are used to support the modelling. The work is being continued in 2005, including modelling the heat transfer in short copper tubes and measuring the temperatures during the welding of lids in support of the modelling results.

Posiva was involved in SKB's development work on the low-vacuum electron beam welding method and the friction stir welding (FSW) method. To support this work, studies were conducted, for instance, to establish the properties of material welded with the FSW method and equipment suitable for both the EBW and the FSW methods was designed to measure the temperature of the material and/or the tool during welding.

The TEKES/EU project implemented by the Technical Research Centre of Finland (VTT) and Helsinki University of Technology with a view to increasing domestic expertise and resources in the field of FSW technology is nearing completion. The targets set for the project have been achieved, since within the project Finland has acquired one FSW licence for Helsinki University of Technology and one set of production equipment (KTM Tekniikka, Kankaanpää).

A copper billet machined axially to the very centre to find any casting defects.

Development engineer Timo Salonen behind the welded plate samples.

A domestic expert and equipment network of the inspection technology of copper plates and lids was built. Negotiations were conducted in Finland to plan a qualification procedure, and Posiva also took part in the development programme led by SKB aimed to draw up a preliminary proposal for a qualification plan covering the entire canister production chain.

Design of the encapsulation plant

With regard to designs for the encapsulation plant, a compilation was made of the documented encapsulation plant alternatives, and it was supplemented with the design modifications that had so far not been documented.

SKB assigned the task of collecting the documents required for a construction licence to the INKA project. Posiva attended the "Projektgrupp" and "Teknik" meetings of the INKA project, commented on the design documents and compared SKB's and Posiva's designs for the encapsulation plant. The compared issues included the design bases, costs, designs for the systems and components, and regulatory guides and requirements.

A report entitled "Description of the above ground facilities of the Olkiluoto final disposal facility" was drawn up as part of the design of the repository. The report also contains an updated description of the encapsulation plant design.

The design of the docking station of the fuel-handling chamber at the encapsulation plant was ordered from Afore Oy and the work is in the start-up phase.

Material required to support the selection of the encapsulation plant alternative to be further developed was prepared, and Posiva was involved in designing the extension of TVO's KPA Store and the interim storage systems.

Fuel transportation

The cost estimates for the road, rail and sea transportation alternatives of spent fuel were updated.

Nuclear material safeguards

To be able to later dispose of spent fuel in the ONKALO underground rock characterisation facility, which is under construction, STUK's Guides YVL 6.9 and YVL 8.5 are being complied with in ONKALO. Preparation of a manual for the nuclear material safeguards in accordance with Guide YVL 6.9 was launched to implement the nuclear material safeguards. The first draft of the manual will be completed by the end of March 2005 and the manual will be brought into use during 2005 after STUK has approved it.

Basic data for design of the repository and the construction methods

The basic data for design constitutes, to a great extent, the data required during the building stage, which is utilised in the design of ONKALO and the repository. Basic data is needed, for instance, to design the layout of the repository spaces, and to design and implement the excavation, reinforcement and grouting work. This package of tasks is divided into the development work linked with rock excavation and the work that supports design of the actual repository.

Posiva is involved in SKB's APSE project (Äspö Pillar Stability Experiment), in which the rock pillar between two full-scale, differently pressurised deposition holes is fractured. The force required for the fracturing is produced by geometrically forming the tunnel in the test area and, thereafter, by heating the rock in the test area in such a manner that its stress rises high enough in terms of the failure. The objective is to verify in full scale the behaviour of rock described with the aid of models and, in particular, to establish the effect of the backfilling support pressure on the failure. Another objective is to acquire practical experience of the rock breaking and its detection with measuring devices with a view to monitoring the underground spaces during excavation. During 2004, Posiva finished and reported on the 3D modelling of the test performed with a new type of linked numerical method, in which the formation of microfractures in the points essential for the test was simulated with the particle flow code, while the deformations in the surrounding area were modelled with the more conventional finite-element method. The modelling simulated the generation and expansion of fractures in fractured areas. The modelling shows that fragmental microfracturing is generated in the fracturing areas first, but at a later stage the fracturing begins to concentrate, finally forming single fractures, which in the end lead to weakening and failure. The experimental part of the test was carried out in summer 2004, when the rock pillar between the experimental full-scale final disposal holes was fractured. Analysis of the results and comparison between the modelling results and the actual discovered fractures began in autumn 2004 and continues to be underway.

Development work on grouting materials that generate a low pH (pH ≤11) is underway as a co-operation project of Posiva, SKB and NUMO. On the basis of laboratory tests and preliminary field tests, the work concentrated on developing a mixture of cement and silica, whose optimisation is being continued in 2005. As part of the development work, requirements for low-pH grouting cements were assessed and their long-term safety and environmental aspects were examined. Some of the alternative materials had to be rejected owing to potential risks linked with long-term safety.

To ensure a tight final result at the final disposal depth, the objective is also to develop grouting materials whose penetrability is better than that of cement. The studies and field tests conducted in Sweden showed that silica sol was the most promising material to penetrate into small fractures.

Development of the basic concepts for final disposal

Posiva and SKB are jointly carrying out a long-term project (2002–2007) concerning the horizontal disposal concept of the canister. This basic concept is called the KBS-3H concept, to distinguish it from the concept in which the canister is placed in the vertical position (KBS-3V). The installation technique involves a new type of concept in which the canisters and bentonite blocks packed into perforated steel containers would be installed in about 200-m-long horizontal deposition tunnels. Considerably less rock needs to be excavated in this concept than in the vertical disposal concept. The work is being done in several phases. The objective of the development programme is to enhance the KBS-3H concept so as to reach the level of the KBS-3V concept in technical terms, and to demonstrate the drilling of deposition tunnels and the installation of canisters and bentonite blocks in the long horizontal tunnels.

During 2004, the tender documents for the installation equipment of the bentonite/canister package were completed, the invitation for tenders was conducted, and the further designer and the future manufacturer of the equipment were selected. This activity is being carried out as a part of the EU's ESDRED project. Furthermore, the KBS-3H final disposal package was further designed and dimensioned. Safety studies conducted in 2004 are discussed above in the chapter concerning safety analysis.

In the KBS-3H project, an important area of design was also developing the drilling technique for the deposition tunnels. The blind drilling of the first 15-m-long pilot hole was performed in the autumn of 2004. The pilot hole was thereafter enlarged with a new type of technique so as to have a diameter of 1.8 m and to become a horizontal KBS-3H deposition tunnel. The purpose of the drilling was to demonstrate the performance of both the pilot hole drilling and the enlargement technique as well as their further development needs. Towards the end of 2004, an about 70-m-long pilot hole was drilled by the next, longer deposition tunnel. The second pilot hole will be enlarged to its final size in early 2005.

As part of the ESDRED project, the sealing plug of the KBS-3H tunnel based on shotcreting was developed under ENRESA's direction. The plug will be constructed in the 15-m-long tunnel drilled at Äspö during 2005.

As for studies into the properties of buffer bentonite in 2004, Posiva was mainly involved in international co-operation. Some of the bentonite studies are conducted as part of the technical design work under the KBS-3H project, in which studies into the technical designs of bentonite blocks continued in 2004 with laboratory tests on different scales, whose purpose was to technically solve the problems linked with the development of bentonite in the initial phase of final disposal.

The summary report of the EU's "Cluster Repository Project - A Basis for Evaluating and Developing Concepts of Final Repositories for High-level Radioactive Waste (CROP)", which was completed in 2004, described the different final disposal concepts and observations about them.

In 2003, Posiva and SKB jointly launched a long-term programme linked with backfilling of the repository. Descriptions of the different backfilling alternatives were drawn up and the most feasible methods were selected for further development in the first phase. The second phase was launched in 2004 with the objective of providing deeper insight into the different concepts. The selected concepts were a mixture of crushed rock and bentonite and expansive natural clay compacted *in situ* and the use of precompressed clay blocks. Laboratory studies concentrated on the necessary compaction power to fulfil the requirements and on the compaction methods for compaction *in situ*. With regard to precompressed blocks, properties of the materials were studied and tests linked with the manufacture and installation were carried out. Work on the second phase is being continued in 2005.

It has been planned that European Ca-Mg bentonites can be used for tunnel backfilling, and Posiva is co-operating with, for instance, the Czech RAWRA to characterise montmorillonite-rich clay deposits in the Czech Republic. Work on the final report of the project began at the end of 2004.

Technical design of the repository

The second part of the preliminary design stage of the repository was launched in 2004; its objective is to produce a technical solution that is increasingly Olkiluoto-specific. The reference solution of this design, which is scheduled for completion in 2006, is a final disposal design in accordance with the KBS-3V concept. The design work launched in 2004 takes account of the importance of OL3 for the repository and its operations. The plans for 2004–2006 will include studies on the extension of the facilities for a larger fuel volume and on the application of multi-storey concepts to the Olkiluoto bedrock. A two-storey concept is feasible for both the vertical and the horizontal disposal concepts. Thermal optimisation of the dimensioning of the repository is also being performed.

In the design period of 2004–2006, studies will also pertain to the stepwise implementation of the repository spaces, and the construction, operation and sealing of the repository. The studies will also contain a description of the safeguards of nuclear materials, radiation protection principles and operation in the event of incidents and accidents.

With respect to systems design, basic systems for the ventilation of the repository were assessed in 2004. The first task is to lay down the principles for the ventilation of ONKALO, which will thus provide a basis for the ventilation system of the repository.

In 2004, the plan for the transport and installation vehicle was further developed to also become suitable for transport of the canister on the inclined ramp. The vehicle moves on a crawler base, whose benefits include a high weight-carrying capacity even on uneven ground, a small fire load and a narrow turning radius of the vehicle.

The Äspö Hard Rock Laboratory

SKB and Posiva mostly operated within the co-operation framework as in previous years. In addition to this, several joint projects were launched or planned during the year, which are not directly included in the co-operation programme at Äspö, but in which it will be possible to utilise the Äspö Hard Rock Laboratory or ONKALO for making demonstrations in the future. These joint projects include, for instance, development work on the KBS-3H concept, development work on the low-pH cement and the joint project on backfilling technology (further information on the above-mentioned projects can be found under, e.g., "Final disposal technology").

At Olkiluoto, Posiva is mainly concentrating on research into the bedrock conditions and into the assessment of site-specific or site-dependent factors. General development of the rock construction methods for the repository can also be implemented in ONKALO. At Äspö, Posiva is performing the general verification and demonstration of operations linked with engineered barriers and repository technology. Field tests that provide a basis for the assessment of long-term safety are carried out at Äspö linked with the performance of the bedrock as a natural barrier.

The investigations to be carried out at the Äspö Hard Rock Laboratory within the framework of international co-operation have been grouped as follows:

– investigations linked with technology;
– investigations linked with geosciences;
– investigations linked with natural barriers;
– investigations linked with operations of the Äspö Hard Rock Laboratory.

Posiva is involved in the "Prototype Repository" project, which is implemented at SKB's Äspö Hard Rock Laboratory. The project was accepted into the EU's framework programme for 2000-2003. The KBS-3 final disposal concept is being tested and demonstrated in the project by constructing a full-scale long-term test for a sealed final disposal tunnel. During 2001, canister models fitted with heaters and surrounded by compacted bentonite were placed in four full-scale deposition holes. In addition, the tunnel was equipped with instrumentation, and a sampling system was also installed. Finally, the tunnel was filled with a mixture of crushed stone and bentonite, and closed by a solid concrete structure. In 2003, canisters were installed in the tunnel section of the second phase in two deposition holes lined with bentonite, the open tunnel section was filled with a mixture of crushed stone and bentonite, and it was fitted with a concrete plug. The actual test began in the autumn of 2004.

Posiva is involved in the LOT test (Long-Term Test of Buffer Material) to be carried out at the Äspö Hard Rock Laboratory. The test pertains to validating the hypotheses and models of long-term processes occurring in the buffer material, and the closely linked processes concerning microbiology, the migration of radionuclides, copper corrosion and the migration of gas. The tests are performed at a depth of about 500 m, in boreholes drilled in the tunnel bottom; the boreholes have a diameter of 30 cm and a depth of 4 m. The tests to be performed in five boreholes were begun in 1999, and they have been planned to last for 1, 5 and 20 years.

Posiva is taking part in the four-year international working group organised by the Äspö Hard Rock Laboratory, which was launched in 2004, whose task is to model the behaviour of the engineered barrier system (EBS) under the final disposal conditions. Posiva is involved in the subproject that models the thermohydromechanical (THM) behaviour of the processes occurring in the buffer bentonite and tunnel backfilling material as well as in the near-field of the bedrock during saturation. In 2004, the modelling pertained, for example, to the free expansion of bentonite. In 2005, the simulation will concern the THM(C) behaviour of the EBS in the KBS-3V and KBS-3H concepts, considering the effects produced by installation holes. The modelling work to be conducted is linked with the EU project dealing with processes in the near-field (NF-PRO) and with the master's thesis entitled 'Thermo-Hydro-Mechanical Analyses of KBS-3V Deposition Hole' (A. Lempinen) to be published in 2005.

Posiva and SKB jointly launched the first phase of the project linked with backfilling of the repository. The objectives of the first phase were to describe the optional backfilling methods that had been determined together and to assess their performance from the viewpoint of the requirements, and to select the most feasible methods for further development and to assess the volume of the required research and development work before commissioning of the repository. The work of the second phase launched in 2004 consists of studying the materials of the selected concepts as well as designing and testing the manufacturing and installation technology on a small scale.

Posiva was involved in SKB's APSE project (Äspö Pillar Stability Experiment), whose purpose is to carry out a large-scale failure test on the pillar between two final disposal holes.

The objectives of the work are:

– to test the opportunities for predicting the strength behaviour of crystalline, hard rock on the tunnel scale and in an intense stress field using numerical modelling programs FLAC3D and PFC2D. In addition, the linked program FLAC2D/PFC2D was applied as a completely new one.
– to acquire practical experience in the monitoring of rock damage using, for instance, acoustic emission (AE) measurements and to compare the measured responses with the modelled results. AE is a

highly feasible and interesting method to use during construction of ONKALO as well.
– to demonstrate and further improve opportunities to control growth of the EDZ zone. The test will examine the effect of the pressure prevailing in one hole on the propagation of fractures.

During 2003, Posiva took part in the practical implementation and design of the failure test. In addition, Posiva was involved in the excavation project of the APSE tunnel, which also investigated issues linked with the feasibility for grouting and the effect of blasting diagrams on the excavation result. The failure test was modelled by performing thermomechanical analyses with both the FLAC3D program and the linked FLAC2D/PFC2D program. The preliminary FLAC3D analyses were reported in SKB's IPR series of reports published in 2003. A report on the detailed analyses was completed in early 2004. The actual failure test was launched at the end of 2003 with excavation of the first final disposal hole. The second final disposal hole was excavated in the beginning of 2004 and the actual failure test was carried out in summer after the heating phase.

The objective of the borehole cleaning and sealing project is to develop a concept for the sealing of investigation boreholes drilled near the repository. The sealing prevents the investigation boreholes from functioning as potential migration paths of groundwater in the bedrock, which is necessary for long-term safety of the repository. In addition to issues related to the actual plug, the project also includes the cleaning and stabilisation of the investigation boreholes.

The project began with a feasibility study in 2002. Phase 2 was launched in 2003 and it finished at the end of 2004. Phase 3 is scheduled for 2005–2006. The objectives of the second phase of the project were a) to develop a method that would possibly fulfil the requirements set for the sealing, and b) to make a recommendation for the full-scale tests to be conducted in phase 3. Posiva was involved in the work of phase 2 by drawing up a report on the cleaning of the investigation boreholes, which was used as a background report for the report describing the sealing concept, which SKB published at the end of 2004. Posiva also took part in the operation of the project group in 2004.

DESIGN OF THE UNDERGROUND CHARACTERISATION FACILITY

Before a decision to construct a repository is taken, supplementary bedrock investigations will be carried out at Olkiluoto for the implementation design of the facilities. An underground rock characterisation facility, known as ONKALO, will be constructed for the investigations and design. Excavation of the open cut began in summer and excavation of the tunnel in autumn 2004.

ONKALO should be constructed to allow underground investigations for site confirmation without jeopardising long-term safety of the repository site. In addition, it should be possible to later link ONKALO by incorporating it into the repository.

In the preliminary design stage of ONKALO in 2001, the alternatives that included at least two separate access routes were considered feasible in terms of operational safety. In the outline planning stage in 2002, two alternative draft designs were drawn up on the basis of the preliminary design: the shaft alternative and the access tunnel alternative. After the evaluation, the access tunnel alternative was chosen as the basis for the main drawings stage of ONKALO owing to, for instance, the higher flexibility, the greater feasibility for investigations and the better working conditions. The main drawings stage ended with submission of the application for a building permit to the municipality of Eurajoki in May 2003. The implementation plan material and the supply documents were completed for the invitation for tenders for the first tunnel contract towards the end of 2003.

The first tunnel contract was signed in the spring of 2004 and it covers the excavation and structures of the access tunnel (to level –417 m) near the main characterisation level and raise boring of the shaft to level –287 m. Design of the building stage began at the same time. Designs for the systems during construction related, for instance, to ventilation and pumping, were updated with the contractor. Designs for the open cut were supplemented on the basis of the observations made during excavation and the designs for the technical building were finished to be ready for submission of the application for a building permit. Layout of the access tunnel was fine-tuned on the basis of the updating of the bedrock model. An additional connection was already designed to level –11 m to simplify the construction work and the ventilation system.

Construction of the underground rock characterisation facility

In summer 2004, a new research hall of 380 m^2 was put into use in the ONKALO area. The research hall includes an investigation room for drill core samples, where the rock samples can be spread over a distance of several hundred metres and the rock material of the borehole can be analysed over the full borehole length. The researchers have worked intensively in the hall, which has considerably enhanced and accelerated the analysis of drill cores. In the research hall there is also a sound-proof sawing room for the sawing of samples. The occurrence of minerals in drill core samples, for instance, is investigated in the microscopy room. The area of the storage building is 250 square metres and rock samples, among other things, will be stored there.

The field laboratory of the research hall, which was completed during the year under review, facilitated the pretreatment and preparation of water samples before sending them to other laboratories, although the laboratory is also fitted with equipment for simple analyses.

The preparations above ground at the ONKALO site began in June 2004. The first work consisted of erecting the site huts and digging land masses from the entrance to ONKALO. The initiation blast for ONKALO was set off on 29 June. The Minister of Social Affairs and Health, Sinikka Mönkäre, honoured the occasion with her presence, and representatives of the media were also present.

The excavation work began with excavation of the open cut, which was completed on 6 September 2004. The excavation of the tunnel began with the bolting and grouting of the tunnel portal. The actual excavation of the tunnel began on 22 September 2004. The first rounds were blasted in many stages and carefully. The purpose of careful excavation was to limit the loosening of rock to as little as possible.

One near-miss case and one accident occurred at the site in 2004. In both cases, it was a question of a loose block, which in the near-miss case fell close to a geologist and in the accident case on the helmet. The latter resulted in a four-day sick leave. Particular attention has been focused on occupational safety issues at our unique site. Both the purchaser and the contractor work in the spirit of "zero accidents".

Of the area work that supports the tunnel excavation, the work included in the first and second phases of the contract was completed. The work consisted, for instance, of the research hall, the drilling and discharge water systems, the settling basin and the pump building. The site fence, area lighting and the technical building will be completed in the last, i.e. the third, phase.

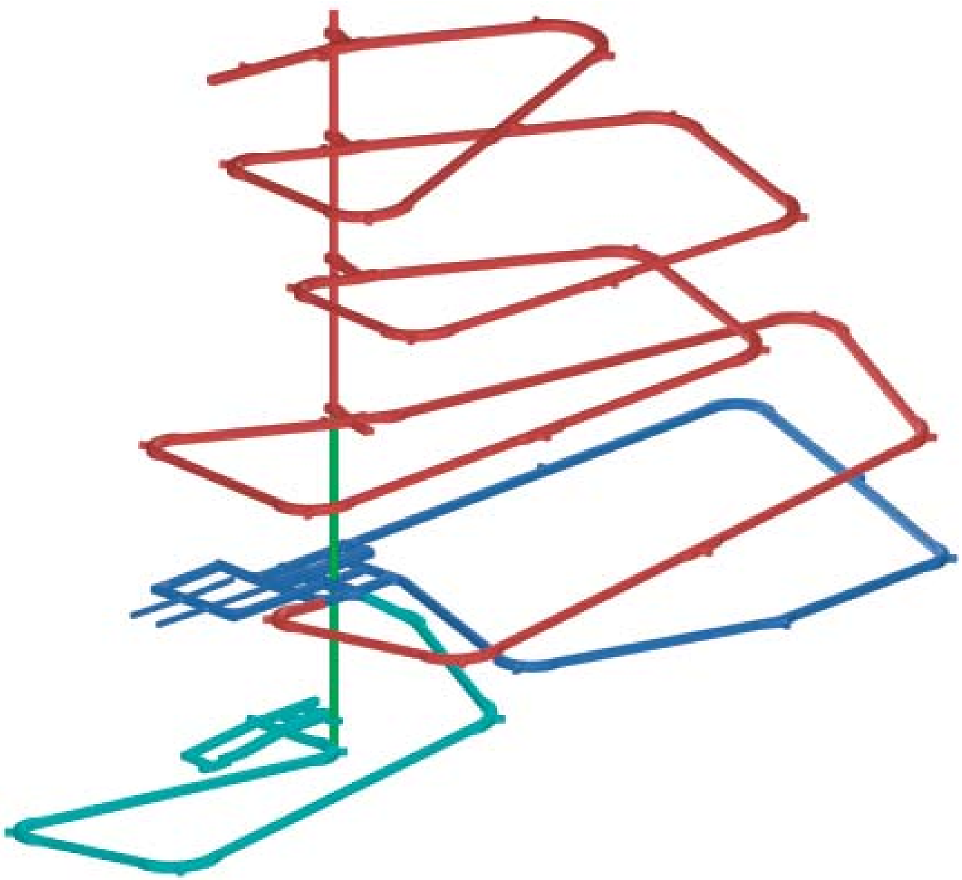
The area work included in the contract agreed to be conducted by Kalliorakennus Oy is still underway. The work is planned to be completed in the summer of 2005. The work consists, for example, of building the sustaining walls of the tunnel.

The excavation work progressed more slowly than expected in the original schedule. The speed of tunnelling will increase owing to new equipment and the decreasing volumes of grouting material. The tunnel progressed at about 15 to 20 m a week.

Bedrock investigations were carried out as part of the excavation work. They support both the design and construction of ONKALO and the characterisation of bedrock in the final disposal area. The investigations include geological mapping and the drilling of probe and pilot boreholes. After every fourth excavation round (at intervals of about 20 metres), four about 26-m-long probe boreholes were drilled, and flow and water consumption measurements were carried out in them. The results will be used to determine the need for pre-grouting in the tunnel. The ROCMA equipment, which is connected to the new DATA drilling jumbo, will be brought into operation in the beginning of 2005. The equipment will help assess variations occurring in the bedrock properties. This will supplement other measurements conducted in the probe boreholes.

In the early stages of the tunnelling, the rock has been grouted using some 100,000 kg of fine cement. The consumption of grout per grouting round has reduced to half the consumption during the first five grouting rounds. This means that the rock is now tighter than previously. The grouting has succeeded well, since the amount of water seeping into the tunnel was measured to be 0.15 litres/min/100 tunnel -metres.

Parameters by the end of the year:
- Total length of the tunnel 157 m
- Excavation volume some 6,250 m^3
- Consumption of the grout 106,000 kg.



Layout of ONKALO was fine-tuned and an additional connection was already designed from level –11 m. The scope of the first tunnel contract is shown in red.

MANAGEMENT OF OPERATING WASTE

In addition to high-level spent fuel, the Olkiluoto and Loviisa Power Plants produce intermediate- and low-level nuclear waste, comprising used reactor internals (e.g., control rods and core instruments) and plant operating waste (e.g., ion-exchange resins and miscellaneous maintenance waste). The management of used reactor internals is discussed in the section entitled "Decommissioning investigations". The management of operating waste is discussed below.

OLKILUOTO POWER PLANT

Principles and schedule

Most of the operating waste is packaged immediately for handling, storage and final disposal. The intermediate-level ion-exchange resins used to clean the process water are solidified into bitumen, and the mixture is cast into steel drums. Some of the low-level waste (compressible miscellaneous maintenance waste) is compacted into the steel drums with a hydraulic press, and some (metal scrap and filter rods) is packed as such into steel containers, concrete boxes and steel drums. Drums containing compressible waste are further compacted so that the final height of the drums is approximately one half of the original (the diameter, however, does not change). Metal scrap can also be compacted before packaging. With the aid of the metal shredder acquired in autumn 2004 it is possible to fill empty space remaining in the concrete boxes that are taken to the repository with shredded metal and thus the volumetric efficiency of the packaged metal waste is increased. Miscellaneous liquid waste and sludge are solidified by mixing the waste with a binding agent in a drum that also serves to contain the solidified mixture.

Operating waste is stored temporarily at the plant units, in the storage facility for intermediate-level waste (KAJ Store), in the storage facility for low-level waste (MAJ Store), in the enclosed storage area and, to a minor extent, in the KPA Store, at the Olkiluoto plant site. Intermediate- and low-level waste produced during power plant operation is disposed of in the present waste silos of the repository for operating waste (VLJ Repository). Very low-level waste is exempted from regulatory control and is either transported to the dump at the Olkiluoto plant site or handed over, for example, to be processed for reuse.

Current status of storage and final disposal

The table below shows the current status of storage and final disposal at the end of 2004. The waste has been packed into drums (200 litres each, or about 100 litres in compacted form), steel containers (1.3 or 1.4 m^3 each) and concrete boxes (net 5.2 m^3 each). In addition, Studsvik Energiteknik AB held five drums of low-level ash generated in an incineration test in their storage facility in Studsvik, Sweden. If necessary, the drums and containers are stored in the storage facilities of the plant units and the KAJ Store before final disposal in the VLJ Repository. Before transfer to the VLJ Repository, the drums and steel containers were placed in large (net 5.2 m^3 each) or small (net 3.9 m^3 each) concrete boxes, the large boxes housing 16 drums or 7 drums and 2 steel containers, and the small boxes 12 drums. Correspondingly, the concrete boxes will house twice as many compacted drums.

Bulky contaminated metal components are stored in the KAJ Store and the adjoining enclosed storage area. In addition, unpacked operating wastes, such as used ventilation filters and non-bituminised resins, are stored at the

Operating waste produced at the Olkiluoto Power Plant

	Total volume of waste		In the VLJ Repository		
			KAJ Silo	MAJ Silo	Total
	(pcs)	(m^3)	(pcs)	(pcs)	(m^3)
Bituminised waste	7,097	1,420	6,830		1,366
Other operating waste					
– in drums	6,338	1,112		6,077	1,060
– in steel containers	455	632	5	450	632
– in concrete boxes	223	1,159	19	189	1,082
– unpacked		360			
Total		**4,683**			**4,140**

plant units, and waste oil in the KPA Store. Some of the metal scrap will be disposed of as such in the concrete boxes used in the VLJ Repository. Some of the unpacked waste will later be exempt from regulatory control and will either be reused or transported to a dump. For example, very low-level waste oil may be exempt and reused. At the end of 2004, the amount of such waste oil was 18 m^3.

The waste storage facilities of the power plant units can house some 1,000 drums each. The MAJ Store mainly houses only very low-level maintenance waste bags and scrap, which will be exempt from regulatory control. The KAJ Store can house drums, containers and bulky, contaminated metal components, the total volume of which comprises some 6,000 drums.

The capacity of the intermediate-level waste silo in the VLJ Repository is 17,360 drums (200 litres each) and that of the low-level waste silo 24,800 drums, i.e. about 8,400 m^3 of operating waste packed in drums, or the equivalent of the waste accumulated during 40 years of operation of the two power plant units at Olkiluoto. Additional repository facilities can be built in the same bedrock area, if necessary.

Radioactive wastes from small producers are stored in the VLJ Repository at Olkiluoto. The Radiation and Nuclear Safety Authority (STUK) has so far been in charge of these wastes, which consist of radioactive material used mainly in hospitals, research institutes and industrial plants. By the end of 2004, 45 m^3 of this waste had accumulated in the VLJ Repository.

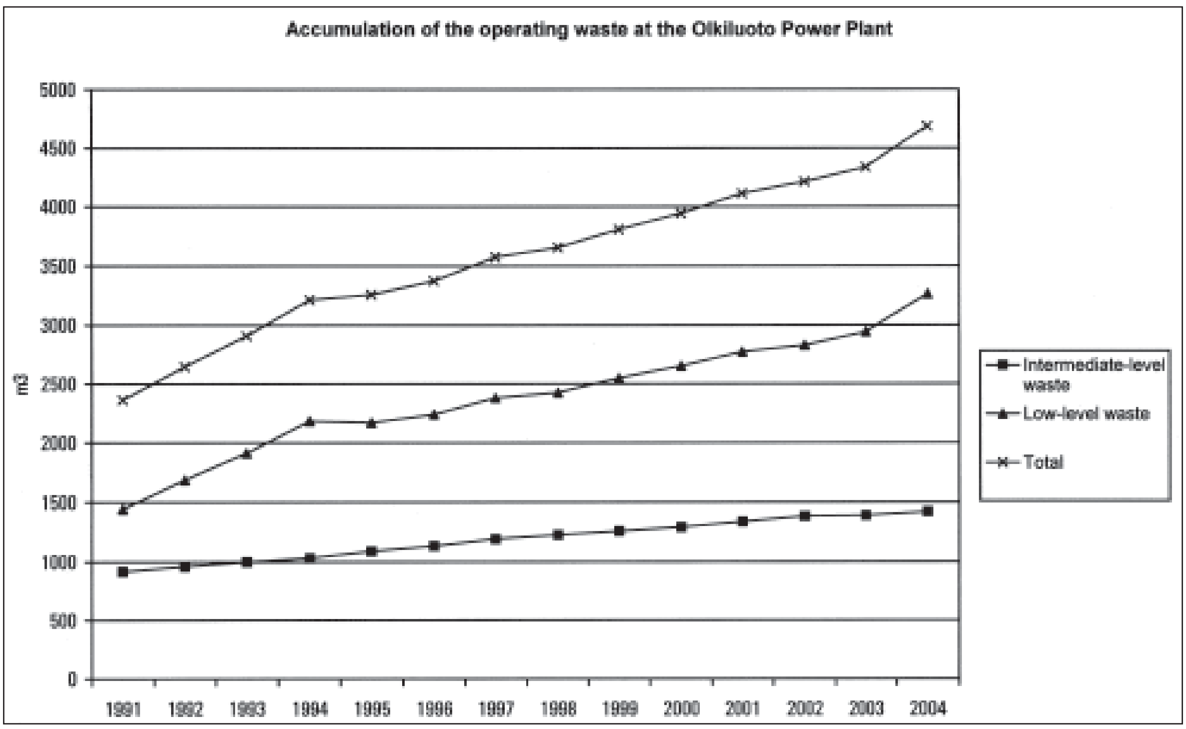
Studies on operating waste

A large-scale test of the microbiological degradation of low-level maintenance waste is being conducted in the construction tunnel of the VLJ Repository. The project was launched as part of the PROGRESS project of the EU's nuclear fission safety programme in 1997. These studies are conducted to determine more exact estimates of the volume of gases generated by maintenance waste, and in order to gain a better understanding of the entire degradation process under the conditions that correspond to the situation after the sealing of the VLJ Repository. This project also involves monitoring the migration of activity from the waste drums to the surrounding water.

In the gas generation test, the pH in the tank was roughly unchanged at the tank bottom and slightly lowered on the lid level of the drums. It seems that the amount of cultivable microbes has increased during the year under review, both in drums that contain biodegradable waste and in those containing non-biodegradable waste. Visual examination showed that the waste materials had mostly remained unchanged. The corrosion of carbon steel plate is considerably faster in a drum that contains biodegradable waste than in the other drums of the test.

In the tank, the dominating microbe species have changed during the test, and the populations on the surface and bottom levels differ. On the basis of the reference data on the result sequences, it can be assumed that many of the microbes occurring in the tank water do not represent known species. In 2004, VTT Biotechnology made microbiological assays of two water samples and carried out the microbiological analysis of the solids in five canisters.

TVO and BNFL made the following agreement concerning the modelling of the gas generation test: TVO gets the results of the modelling for its use, while BNFL gets the results of the



test for its use. The agreement continued to be under examination at BNFL.

The calcium and magnesium contents of the test tank increased slightly. In 2004, the iron content was nearly triple compared with the results of 2003. The ammonium content continued to rise. Of the gases, methane is the main gas. In September 2004, the cumulative total gas amount was 5,250 l. The monthly production was about 50 to 70 l, which continues to be clearly below the value used in the safety analysis.

Studies during the operating period of the VLJ Repository

Operation-time monitoring of the VLJ Repository continued in 2004 in accordance with the research and monitoring programme drawn up previously. Under the programme, extensive measurements are carried out at intervals of three years and additional measurements are taken, if necessary. The last time the extensive measurement programme was implemented was in 2003. The water chemistry of groundwater station PVA2 is monitored annually. The water quality at the groundwater stations of the VLJ Repository at Olkiluoto has been monitored since the latter part of the 1980s.

In spring 1993, ten test bolts were installed in the research tunnel of the VLJ Repository at Olkiluoto to establish the corrosion rate of the bedrock bolts. The objective of the test is to obtain information on the corrosion resistance of galvanised reinforcement bolts in the bedrock under the conditions of the VLJ Repository at Olkiluoto, with the hypothesis that the cement mortar protecting the bedrock bolts completely loses its protective property. The first test bolt was removed by core drilling in 1996 and the second bolt in 2004.

Since the bedrock bolts had remained unchanged, support tests were launched in 1998 to study the corrosion behaviour of galvanised steel in the borehole of the bedrock bolt removed from the research tunnel (“Bolt 7”). Thin galvanised steel plates and concrete cylinders were installed in the borehole, thus seeking to regulate the groundwater pH so as to make it more alkaline, and thereby simulating the actual environment of the reinforcement bolts in the operating conditions. Since the water chemistry in the above borehole has not been stable and the corrosion rate of the samples was contrary to expectations, a decision was taken to transfer the samples to the borehole located in the construction tunnel (VLJ-KR9). The water chemistry and conditions of the new disposal hole were studied in spring 2002, and 18 new zinc-coated steel plates and 16 zinc plates were installed in the borehole with the concrete cylinders in September 2002. The water chemistry of the disposal hole is monitored annually. After one test-year, no corrosion could be detected in the zinc-coated steel plate samples. The corrosion of zinc plates (three years) had not progressed in the new test hole. In 2004, no samples were collected, but the zinc-coated steel plates and zinc plates were examined visually.

LOVIISA POWER PLANT

Principles and schedule

Intermediate- and low-level operating waste is conditioned and stored at the plant site. Spent ion-exchange resins and evaporator concentrates are stored temporarily without solidification in tanks in the liquid waste storage facility.

Compilation of the preliminary safety analysis report (PSAR) of a cementation-based solidification plant began towards the end of 1997. The preliminary safety analysis report was submitted to STUK for approval in the beginning of 2000 and it was approved in the spring of 2001. Preliminary design of the solidification plant began in 2002 and the implementation design towards the end of 2003. The construction was launched in early 2004. The solidification plant is scheduled for completion at the end of 2006.

Fortum has invested heavily in the development of new waste-treatment methods. These efforts have resulted in a waste-treatment method that separates caesium from the evaporator concentrate and reduces the waste to a very small volume. The evaporator concentrate is then so clean that a larger volume than previously can be exempt from regulatory control without increasing the annual activity release.

Dry maintenance waste from power plant maintenance and repair work is packed in steel drums of 200 litres each. Compressible waste is compacted into drums with a hydraulic press, thereby reducing the volume by a factor of 3 to 4.

Intermediate- and low-level operating waste from the Loviisa Power Plant is disposed of in an underground repository built in the bedrock at the power plant site. The repository was put into operation as an interim store in the spring of 1997. The repository received an operating licence in the spring of 1998, and the repository has been used for the final disposal of maintenance waste since the summer of 1999.

Current status of storage

In 2004, a study was conducted at the Loviisa Power Plant concerning improvement of the treatment and storage facilities for operating waste. A memorandum on the current status of waste treatment and storage and on the future plans was submitted to STUK in December 2004. As far as the most important changes in the treatment and storage of operating waste are concerned, the following facts can be stated:

– The wastes produced in 1995–2003 and now exempted from regulatory control were taken to the Keltakangas waste centre of Kymenlaakson Jäte Oy.
– The decontaminated metal waste and other metal waste free from radioactivity are stored temporarily in the former sandblasting hall to await exemption from regulatory control. Space is thus cleared in the metal scrap store of LO1 for maintenance waste drums and at the waste-packing plant. It will be possible to perform the soaking-solidification of solvent wastes in spring 2005 and the rooms below waste-

packing plant 1A0343 will become free for use as interim stores for more active maintenance waste drums, oils and solvents. The sorting table and sack monitor for wastes can now be put into use at the waste-packing plant. STUK approved the plan in December 2004.
- About 9 m^3 of miscellaneous low-level solvent wastes, mainly motor washing agent, have accumulated during operation of the power plant. The soaking-solidification of solvent wastes will be performed in October 2005 using a special solidifying agent in 200-litre drums in a similar manner as has been done at the Olkiluoto Power Plant for years. STUK approved the plan in August 2004.
- A bridge crane was installed in metal scrap store 1A0901 of LO1 in 2004.
- Implementation design of the gate monitor, i.e. the activity and dose rate measuring equipment of vehicles entering and leaving the power plant, began in autumn 2004.
- Construction and installation work of the second stage of the repository is being carried out in 2004–2006. Completion of the previously excavated maintenance waste room 2 (HJT2) began in November 2004, and this room will be put into operation as a final disposal facility in May 2005 at the latest. Construction and installation work of the previously excavated final disposal hall for solidified waste (KJT) will begin in March 2005 and it will be completed towards the end of 2006, simultaneously with the seepage water pool built in the repository. The disposal hall for solidified waste will be needed for the final disposal of waste packages completed at the solidification plant from the end of 2006 onwards.
- Construction of the solidification plant for active waste began in early 2004 and it will be completed on schedule at the end of 2006.
- The project aimed to renovate/construct the treatment and storage facilities for low-level maintenance waste was launched in December 2004. A basic design will be submitted to STUK for approval after completion of the preliminary design. The design will also include replacement of the gamma spectroscopic measuring equipment for waste drums.

The table below shows the current status of storage and final disposal at the end of 2004.

The final disposal facility

Intermediate- and low-level operating waste produced at the Loviisa Power Plant will be disposed of in a repository constructed in the bedrock of Hästholmen Island. Fortum has been conducting studies on the suitability of the bedrock in the power plant area for the final disposal of waste since the early 1980s. A preliminary safety analysis report on the final disposal facility was completed in 1986. In 1988, the Radiation and Nuclear Safety Authority (STUK) approved the safety analysis report and granted permission, in accordance with the power plant operating licence, for the construction of a repository. Preparatory construction activities began in 1992, and construction started in February 1993.

Excavation work begun in spring 1993 was completed on schedule in December 1995. Construction and installation work was started in November 1995. The installation work was completed on schedule in late 1996, at which time an application for the operating licence of the repository was also submitted. The repository was put into operation as an interim store in spring 1997 and as a final disposal facility in summer 1999.

The final repository comprises a transport tunnel of about 1,100 metres in length, tunnel and hall spaces built at a depth of about 110 metres, and stair and ventilation shafts. The construction of the repository is implemented in two stages. During the first construction stage, all repository spaces and access routes were excavated. These

Operating waste produced at the Loviisa Power Plant

	Total volume of waste At the plant/in the storage buildings (m^3)	In the repository (m^3)	**Share of the storage capacity** (%)	**Activity** (GBq)
Spent ion-exchange resins	445		50	13,892
Evaporator concentrates	614		58	390
Maintenance waste	332	1,234		487
Total	**1,391**	**1,234**		**14,769**

included two final disposal tunnels for maintenance waste and a final disposal hall for solidified waste. Only one maintenance waste tunnel and the systems serving the entire repository were completed during this stage.

Construction and installation work of the second stage of the repository is being conducted in 2004–2006. Completion of the previously excavated maintenance waste room 2 (HJT2) began in November 2004, and this room will be put into operation as a final disposal facility in the first part of 2005. Construction and installation work of the previously excavated final disposal hall for solidified waste (KJT) will begin in early 2005 and will be completed towards the end of 2006, simultaneously with the seepage water pool built in the repository. The disposal hall for solidified waste will be needed for the final disposal of waste packages completed at the solidification plant from the end of 2006 onwards.

Separate research programmes have been planned for the study of the transport tunnel and hall areas during operation.

The caesium separation facility

By the end of 2004, a total volume of over 1,100 m^3 of evaporator concentrates was treated at the caesium separation facility with 20 ion-exchanger columns, each with a volume of 8 litres. The efficient separation of caesium from evaporator concentrates is a normal operating procedure at the power plant.

Studies on solidification methods

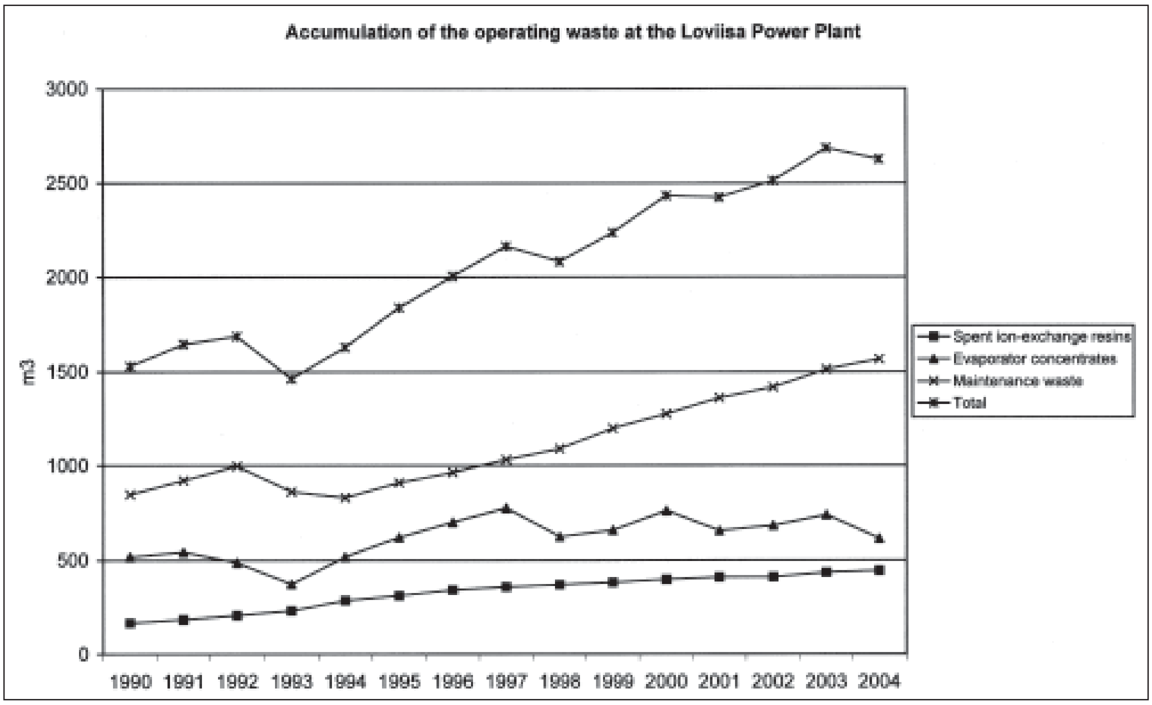
Solidification with cement has been selected as the basic conditioning method for Loviisa's wet operating waste. Verification of the solidification recipes for evaporator concentrates and ion-exchange resins with current building cements continued during the year under review. In addition, test data was obtained from solidification product samples in long-term storage, the oldest of which are now as old as 21 years.

The durability test on ion-exchange resins solidified in half-scale containers in 1987 continued and the test results were reported in 2004. For 17 years now, the waste containers have been immersed in tanks filled with groundwater at the Loviisa Power Plant; as expected, they are still in good condition. No damage to the concrete walls of the containers has been detected, and the composition of the groundwater has remained relatively stable. Activity measurements for the groundwater have not indicated any signs of nuclide release from the solidified products in the concrete containers.

In 1980, inactive ion-exchange resin used at the Loviisa Power Plant was solidified in a full-scale final disposal container. The container was kept in a store until the middle of 1983 and thereafter it has been immersed in slowly flowing fresh water at the Pyhäkoski power plant. The condition of the final disposal container has been monitored after storage of 1, 3, 5, 9, 13, 15 and 21 years. Corrosion is noticeable in the lifting lugs and fastenings made of steel, but no structural damage has been detected on the concrete surfaces of the container, nor has corrosion been discovered in the concrete reinforcements of the container. The test results were reported in 2004 simultaneously with the test results of the half-scale final disposal containers (see List of reports).

Studies during the operating period of the final disposal facility

Operation-time studies on the final disposal facility continued in 2004 in accordance with the monitoring programme. The objective of the programme is to study and monitor long-term changes in the properties and the behaviour of the groundwater and bedrock in the repository and in its immediate vicinity.



The monitoring programme included monitoring the groundwater table in the investigation boreholes above ground once a month. The location of fresh and saline groundwater in the boreholes was measured four times during 2004. In the repository, the conductivity and pressure of groundwater, and the amount of seepage water were measured once a month, the pressure and the amount of seepage water were also measured continuously. The measurements concentrated on seepage water pools and on five groundwater stations built especially for this purpose. In 2004, the hydrogeochemical research programme included water sampling and analysis from groundwater stations LPVA1 and LPVA2. The stability of the bedrock was mainly monitored by an automatic rock mechanical measurement system. Visual checking of the excavated and reinforced rock surfaces for maintenance purposes also continued in 2004.

According to the findings of 2004, the groundwater table follows variations in the seawater level fairly closely, which is a feature typical of Hästholmen. During construction, the groundwater table lowered a few metres in the immediate vicinity of the repository, but a distinct rise was observed after completion of the repository. Owing to the dry summer, however, the groundwater table lowered slightly. The interface between fresh and saline groundwater was between the levels of about -10 and -80 m in the repository area, in other words, distinctly above the repository.

The electrical conductivity measurements of seepage water show that the seepage water is slightly more saline than in the previous year, with the conductivity varying between 1,000 and 1,600 mS/m in different parts of the repository. This means that the repository is practically completely surrounded by saline groundwater. Groundwater analyses show that several parameters of LPVA1 (TDS, Cl, density, electrical conductivity, hardness, SO_4, Na, Ca, Mg, K, Fe, NH_4) have shown a slightly downward trend over the years, but this time a slight increase could be seen, except for sulphate, whose concentration continued to show a decrease. The measurement results of LPVA5 have remained almost constant over the years.

The pressure values of the groundwater clearly reflect the effect of variations in the seawater level. At the five groundwater stations, the pressure varies between 5 and 11 bar, thus corresponding more or less to the pressure at the depth levels of the stations.

The amounts of seepage water were measured at seven points on different sides of the repository. After completion of the excavation in 1996, the total amount of seepage water was about 300 l/min at its highest, from which it has fairly steadily reduced, and was about 100 l/min at the end of 2004. About half of the seepage water continues to come from the transport tunnel and the rest from other facilities. The measurement results show that the maintenance waste rooms are practically dry.

The results of rock mechanical measurements suggest very stable conditions. As in the previous years, the displacements that have taken place in the repository ceilings and walls are very small, distinctly of the order of less than 0.1 mm. Visual examinations also show that the repository is in good condition, and the subsurface drains perform as intended.

Safety of final disposal of operating waste

Construction and installation work of the final disposal hall for solidified waste (KJT) at the Loviisa Power Plant will begin in early 2005 and it will be completed towards the end of 2006, simultaneously with the seepage water pool built in the repository. Updating of the safety analysis of the repository began in spring 2004 and it will be completed at the end of 2005.

International development in the field of the final disposal of operating waste was monitored during the year under review by means of conference visits and trade journals.

JOINT STUDIES

The long-term durability of concrete under final disposal conditions is being studied as a joint project by TVO and Fortum in the VLJ Repository at Olkiluoto and at the Materials and Concrete Laboratory of Contesta Oy (formerly owned by Fortum Technology). The research project pertains to both the operating waste and decommissioning waste management. The studies are discussed in the section entitled “Decommissioning investigations” (Page 31).

DECOMMISSIONING INVESTIGATIONS

OLKILUOTO POWER PLANT

Used reactor internals, which are classified as being intermediate-level operating waste, will not be mainly disposed of until during the decommissioning of the plant. The used reactor internals are stored in the pools of the plant units and a separate inventory is kept of them. By the end of 2004 for instance, 263 control rods and 227 core instruments had accumulated at the Olkiluoto Power Plant. Scrapping of the used steam separators and core grids, which had been stored in the pools of the reactor hall, and their disposal in the VLJ Repository were launched. The steam separator of OL2 was dismantled and the separator groups were disposed of in the VLJ Repository.

The decommissioning plan for the Olkiluoto Power Plant was drawn up in 2003 and the plan will be updated next time in 2008. According to the decommissioning plan, the reactor pressure vessels of the power plant units will be removed and disposed of in one piece. The 2003 plan was based on a power plant unit operating period of about 40 years and on controlled storage of about 30 years before decommissioning. In the future, the plans will be drawn up assuming the plants will operate for 60 years. According to the present plan, the intermediate- and low-level waste from the decommissioning and the used reactor internals from power plant operation will be disposed of in an extension of the VLJ Repository.

The decommissioning investigations are aimed at technical and economic development of the decommissioning plan and specification of the basic data for the safety assessment of final disposal. Activity measurements of various systems within the plant were continued as a means of further developing the activity inventory of the power plant's decommissioning waste. The inventory of activated material will be updated in 2005 to correspond to an operational life of 60 years.

The database built as a part of the decommissioning plan for the contaminated plant section, which was completed in 1989, was transferred to another database application. The database helps calculate the amounts of materials, the amounts of radioactive isotopes, the working hours required for dismantling, dose rates and committed doses of the workers, and the costs. The updating of the database will begin in 2005.

Long-term corrosion tests of carbon steel began towards the end of 1998 in the construction tunnel of the VLJ Repository. The tests are performed jointly with the concrete research in such a way that some of the pieces of carbon steel are placed in the same borehole (VLJ-KR21) as the test samples of concrete while some are in a borehole of their own (VLJKR19). Laboratory tests in the concrete-water and bedrock-groundwater environments were launched in spring 1998. The corrosion rate of the carbon steel samples is determined by the loss in weight and by the volumetric measurement of hydrogen gas. The water chemistry of the boreholes is also monitored by means of monthly pH and conductivity measurements. In addition, water samples are taken annually and certain chemical analyses are carried out.

Samples taken from borehole VLJ-KR21 of the Olkiluoto VLJ Repository have been examined over a test period of about 4.5 years at most. At first, the corrosion rates of steel calculated on the basis of losses in weight were slow (about 1 µm/a), but thereafter the corrosion rates were about 10–19 µm/a. The acceleration of corrosion has been caused by the action of sulphate-reducing bacteria (SRB) in the borehole. In 2004, the samples taken from borehole VLJ-KR21 were examined visually, but no weight-loss measurements were conducted.

In 2001, tests were launched on carbon steel plates without any potential microbial nutrient sources in a borehole where no anaerobic sulphate-reducing bacteria have been detected. On the other hand, sulphate-reducing bacteria (SRB) were detected on the surface of the steel sample taken from borehole VLJ-KR19 in 2004. During the first test-year, the corrosion rate of the plates was about 1 µm/a, and after the second test-year about 1.6 µm/a. In the samples examined in 2004, the corrosion rate was about 1 µm/a again, which means that the conditions in the borehole concerned are evidently stable despite the SRB contamination. On the basis of the weight-loss results, the corrosion of carbon steel continues to be small, although rapid local corrosion has occurred.

The samples placed in borehole YD10 in the Olkiluoto bedrock form a part of the long-term tests begun in 1985, whose purpose is to investigate the behaviour, corrosion properties and gas generation of decommissioning waste metals with the aid of metal samples cast inside test samples. In addition to reference concrete, samples were placed in silica concrete and sulphate-resistant concrete. One series was examined from the samples removed in 2003. The steel bars exposed beneath the concrete were mostly free of rust, and rust was mainly found at the bar ends. The corrosion of steel has been small in the reference concrete. The steel bar placed in silica concrete was most rusty, but the corrosion of the bar ends was most rapid in sulphate-resistant concrete. The corrosion rate of the steel bars placed in the reference concrete and silica concrete is 8–10 µm/a in corrosion pits and about 20 µm/a in sulphate-resistant concrete.

LOVIISA POWER PLANT

Operation of the Loviisa Power Plant results in the accumulation of intermediate- and low-level nuclear waste that will not be disposed of until during the decommissioning of the plant. This waste includes, e.g., used shielding elements, absorbers, neutron flux transducers, intermediate rods of control rods and fission chambers.

By the end of 2004, 146 used shielding elements, 207 absorbers, 204 neutron flux transducers, 128 intermediate rods and nine fission chambers had accumulated at the Loviisa Power Plant. Of these items, the shielding elements have been placed in the plant pools in the spent fuel store, and the absorbers and fission chambers have been stored in specially built channels in the spent fuel store. The neutron flux transducers and intermediate rods have been stored in corresponding channels located in the reactor halls.

In 1987, Fortum drew up a plan and cost estimate for the decommissioning of the Loviisa Power Plant. The decommissioning plans were updated in 1993. The plan was based on 30 years of commercial power plant operation, which is equivalent to the designed technical life of the power plant. However, technical measures may be undertaken to extend the operational life of a nuclear power plant. New studies were completed at the end of 1998, which focused on the effects of revised spent fuel management and the power plant modernisation project on the decommissioning plans and schedules. The operational life of the power plant has also been planned to be extended to 45 years, and this was considered in the studies. According to the updated decommissioning plan, all the radioactive systems not necessary for the remaining nuclear operation (i.e. storage of the spent fuel, solidification of the wet waste and final disposal of low- and intermediate-level waste) at Hästholmen will be dismantled immediately after the shutdown of the power plant.

The plans are revised every five years. The new decommissioning plan was updated during 2003. An operational life of 50 years was chosen as the basis for the updating. The updating consisted of the verification of the activity inventory, dismantling measures, radiation dose estimates, amounts of the components and packages to be disposed of, safety of the final disposal, and estimates of the workload and costs.

In 2004, a study was launched to establish the volume of waste produced from the dismantling of the contaminated sewage pipes left in cast concrete during the construction of the Loviisa plant, and related costs. The study will be completed in 2005.

To update the dismantling plan of the biological shield, concrete samples were taken in 2003 and they were exposed to radiation. Additional information was already obtained from the samples in 2004, and the studies are being pursued to be able to include the updated dismantling plan of the biological shield in the decommissioning plan of 2008.

It is not expedient, however, to make any decisions regarding decommissioning or continued operation until towards the end of the designed technical operational life. It is also advisable to take a final stand on whether the plant will be decommissioned immediately or after a certain delay, just upon termination of the power plant operation, before the beginning of the decommissioning.

JOINT STUDIES

The long-term durability of concrete under final disposal conditions is being studied as a joint project by TVO and Fortum in the VLJ Repository (VLJ-KR20 and VLJ-KR21) at Olkiluoto and at the Materials and Concrete Laboratory of Contesta Oy at Myyrmäki, Vantaa. The project was launched in 1997. This research project, originally co-ordinated by Posiva, concerns both the operating waste and decommissioning waste management. In 2003, TVO assumed responsibility for co-ordinating the project. The purpose of the studies is to realistically assess the long-term behaviour and degradation of concrete in the bedrock-groundwater environment that corresponds to operating conditions. The objective is to establish, using modern concrete technology, the durability and lifespan of the planned concrete types with different compositions under the real final disposal conditions and under accelerated laboratory conditions. Special emphasis will be placed on establishing the most durable concrete compositions under prevailing conditions, which will meet the requirements set for the lifespan.

With regard to the testing of concrete ingredients, the basic tests of concrete technology carried out during 2004 included destructive tests, deformation measurements and analyses of the microstructure. Of the long-term tests, the laboratory tests concerned the carbonation of concrete test samples and the penetration of corrosive components; furthermore, analyses of the microstructure were performed and microstructural maps were determined for the selected concrete test samples in so far as test samples still remained. The long-term tests also included analysing the water of the test-sample storage pool used for the laboratory tests after a storage period of six years.

With respect to the long-term field tests, samples were taken in the autumn of 2004 from the concrete test samples placed in borehole VLJ-KR20. The research conducted on the test samples included the penetration of corrosive components and analyses of the microstructure. The concrete test samples placed in borehole VLJ-KR21 were examined visually. As stated above in the decommissioning investigations concerning carbon steel samples, the water chemistry of the boreholes (VLJ-KR19–21) is monitored by means of monthly pH and conductivity measurements and, in addition, water samples are taken annually and certain chemical analyses are carried out.

COMMUNICATIONS AND CONTACTS

During the year under review, the subjects of external communications included the choice of the contractor for ONKALO, the beginning of the excavation of ONKALO, and the progress of tunnel work. Posiva also demonstrated the construction of ONKALO at the Environment 2004 Fair in Helsinki.

An open house event was arranged for the general public at Olkiluoto in the autumn. Some 1,000 visitors, mainly from the Eurajoki and Rauma areas, became acquainted with the construction of ONKALO during the day.

Plenty of information material related to ONKALO was produced during the year under review. In addition to brochures, an animation recorded in DVD format was produced to illustrate the construction technology of ONKALO and the progress of work. Furthermore, the construction of ONKALO and the change it has brought about in Posiva's operations have guided the overall updating of the visual and factual content of the Company's web site.

The 'Posiva Tutkii' bulletin published as a supplement to the 'Uusi Rauma' and the 'Porin Sanomat' newspapers covered the preparations for the construction of ONKALO and the progress of the excavation.

QUALITY MANAGEMENT AND ENVIRONMENTAL MANAGEMENT

Posiva's operations are aimed at the safe implementation of nuclear waste management in accordance with the needs of its owners and other clients, while protecting the environment and fulfilling the requirements set by society. Posiva has been upgrading quality ever since the Company was established. At Posiva, company operations are guided by the operating system, whose purpose is to verify the systematisation of operations and the achievement of the targets in accordance with the company strategy. During 2004, the Company's main, production and support processes were described in the operating system. A self-assessment event of the support processes was arranged in autumn 2004 with a view to identifying major points of development in these processes.

During 2004, the efficiency and reliability of the system in relation to the set targets were assessed by Posiva's internal audits. The internal audits were concerned, for instance, with risk management and the Company's environmental aspects. The results of the audits brought important subjects of development to light to improve the efficiency of operations and the operating system.

The capability of 18 suppliers to fulfil the technical, economic, quality and environmental requirements was assessed during 2004. The operating systems that are being applied and their development potential were surveyed. The functioning of 13 organisations was assessed by means of the audits of suppliers during the year under review.

Instructions with a view to assuring the quality of research, development and design work were specified. In assuring the quality, Posiva also employed an outside expert group to audit the material produced by Posiva. The quality management of the ONKALO project concentrated on drawing up the quality assurance programme and on determining the guidelines that support the operations.

Quality assurance of the construction of ONKALO was developed by determining the functions during construction important for long-term safety and by dividing them into three classes on the basis of their significance. The following functions were considered to belong to the most significant class with regard to long-term safety: passing of hazardous materials into ONKALO, control of water seepages, drillings performed in the area of ONKALO, and the damage zone caused by excavation (EDZ). Appropriate quality assurance instructions were drawn up for these functions.

As far as TVO and Fortum are concerned, the nuclear waste management operations are within the scope of the quality assurance programmes of nuclear power plants approved by the Radiation and Nuclear Safety Authority (STUK) in accordance with Section 36 of the Nuclear Energy Decree and Guides YVL 1.1 and 1.9. Both nuclear power plants have a certified environmental management system in accordance with the ISO 14001 standard for environmental management.

COSTS

RESEARCH

The total cost of the nuclear waste management research programme was some EUR 14.3 million. The cost estimates for the research programme in 2004 were about EUR 11.2 million. The research programme was mostly implemented as planned.

The above-mentioned costs do not include Posiva's research assignments sponsored by Tekes, the National Technology Agency of Finland.

SUMMARY OF THE RESEARCH COSTS IN 2004

Research area	Costs (EUR million)
Planning, co-ordination, information activities and general studies	0.5
Management of spent fuel and high-level waste	13.5
Management of intermediate-level and low-level waste	0.1
Decommissioning and decommissioning waste	0.2
Total	14.3

FINANCIAL PROVISION FOR NUCLEAR WASTE MANAGEMENT

Funds for the future costs of nuclear waste management are collected by the State Nuclear Waste Management Fund. The fund target is determined according to the liability of nuclear waste management to be confirmed each year. The liability comprises the future costs of the management of all wastes accumulated by the end of the year in question.

EUR 763.8 million was assessed as the fund target for TVO in 2004, the corresponding amount for Fortum being EUR 570.2 million.

The Ministry of Trade and Industry (KTM) confirmed a liability amount of EUR 792.7 million for TVO's nuclear waste management at the end of 2004 and, based on this amount, a fund target of EUR 792.7 million for 2005. For Fortum, KTM confirmed a liability amount of EUR 596.4 million and, accordingly, a fund target of EUR 596.4 million for 2005.

LIST OF REPORTS 2004

POSIVA 2004-01
Reduction of Uranyl Carbonate and Hydroxyl Complexes and Neptunyl Carbonate Complexes Studied with Chemical-Electrochemical Methods and Rixs Spectroscopy
Sergei Butorin, Joseph Nordgren
Uppsala University
Kaija Ollila
VTT
Yngve Albinsson
Chalmers University of Technology
Lars Werme
SKB
May 2004
ISBN 951-652-127-4
33 p.

POSIVA 2004-02
Modelling Gas Migration in Compacted Bentonite: GAMBIT Club Phase 3 Final Report
A. R. Hoch, K. A. Cliffe, B. T. Swift, W. R. Rodwell
Serco Assurance
April 2004
ISBN 951-652-128-2
144 p.

POSIVA 2004-03
Dissolution rates of unirradiated UO_2, UO_2 doped with ^{233}U, and spent fuel under normal atmospheric conditions and under reducing conditions using an isotope dilution method
Kaija Ollila
VTT Processes
Yngve Albinsson
Chalmers Technical University
Virginia Oversby
VMO Konsult
Mark Cowper
AEA Technology
December 2004
ISBN-951-652-129-0
110 p.

POSIVA 2004-04
Updated assessment of health risks on the transportation of spent fuel
Vesa Suolanen, Risto Lautkaski, Jukka Rossi, Tapio Nyman, Tony Rosqvist, Sanna Sonninen
VTT Processes
May 2004
ISBN-951-652-130-4
(in Finnish, abstract in English)
156 p.

POSIVA 2004-05
Localisation of the SR 97 Process Report for Posiva's Spent Fuel Repository at Olkiluoto
Editor:
Kari Rasilainen
May 2004
ISBN-951-652-131-2
168 p.

POSIVA 2004-06
Future Climate Scenarios for Olkiluoto with Emphasis on Permafrost
Jannika Cedercreutz
Helsinki University of Technology
December 2004
ISBN-951-652-132-0
72 p.

Fortum Power and Heat Oy, TJATE-G12-00082
Long-term durability experiments with concrete-based waste packages in simulated repository conditions
Ari Ipatti and Juha Ratvio
Contesta Oy
Vantaa, December 2004
83 p.

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